ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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Tenders to be lodged at Charing Cross Embankment Buildings, W.C.2, by Ten a.m., October 18th.

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G. R.

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Two 450 B.H.P. four-cylinder Engines, with Auxiliary Pumps and Starting Apparatus. One right hand and one left hand. Makers, Sulzer Bros., Switzerland.

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Tenders close Ten a.m., 8th November, 1919.

For Tender Form and Permit to View apply to the CONTROLLER, D.B.1.(E), Charing Cross Embankment Buildings, London, W.C.2.

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Tenders close Ten a.m., 25th October, 1919.

For Tender forms and applications to view, apply to the CONTROLLER, D.B. 1 (H), Charing Cross Embankment Buildings, W.C. 2.

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Detailed list, together with Tender Form and Permits to view, can be obtained from the CONTROLLER, D.B.1.e, Charing Cross Embankment Buildings, W.C. 2.

Note.—*Surplus*, price 3d., the official list of Government Property for sale. Published twice monthly. On sale everywhere. A 700

MANCHESTER CORPORATION GAS DEPARTMENT.

The Gas Committee are Prepared to Receive

Tenders for the Construction

and ERECTION of THREE WATER TUBE BOILERS, each having an evaporation of 12,500 lbs. of water per hour, and fitted with Coke Breeze Travelling Grate Mechanical Stokers complete. Also Boiler Seatings, Economisers, Pumps and Fittings, &c., on the site of their Bradford Road Works.

Specification and Form of Tender may be obtained on application to Mr. FREDE. A. PRICE, Superintendent, Gas Department, Town Hall, Manchester.

The Site may be inspected and any further information obtained on application to Mr. W. NEWBIGGING, Engineer, at his Office, 5, Norfolk Street, Manchester.

Sealed Tenders to be enclosed in the envelope provided for that purpose and addressed to the CHAIRMAN OF THE GAS COMMITTEE, and endorsed "Boilers," Bradford Road Station, and delivered at the Gas Offices, Town Hall, Manchester, not later than Five p.m. on Thursday, the 23rd October, 1919. A 757

SOUTH STAFFORDSHIRE WATERWORKS COMPANY,
Maple Brook Pumping Station.

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Tenders from Engineering

Firms for SUPPLYING and ERECTING a Vertical Triple Expansion PUMPING ENGINE with Force Pumps and Borehole Pumps to be erected in the existing Engine House at their Maple Brook Pumping Station, near Lichfield.

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Forms of Tender, copies of Conditions, Specification and Plans may be obtained from the undersigned.

The lowest or any Tender will not necessarily be accepted.

FRED. J. DIXON, M.Inst.C.E.,
1st October, 1919. Engineer.
36a, Paradise Street,
Birmingham. A 692

METROPOLITAN WATER BOARD.

TENDERS for the SUPPLY and ERECTION of THREE CENTRIFUGAL PUMPS, for Shooters Hill, Woolwich.

The Metropolitan Water Board invite

Tenders, for the Supply and

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Forms of Tender, Conditions of Contract, Specification and Drawings, may be obtained at the Offices of the Board, Chief Engineer's Department, South Place, Finsbury Pavement, E.C. 2, on and after Friday, 10th October, 1919, on production of an official receipt for the sum of £1 1s. (one guinea), which sum must be deposited with the Board's Accountant, at South Place, Finsbury Pavement, and will be returned on receipt of a *bona fide* Tender with all incidental papers.

Such payments and applications must be made between the hours of Ten a.m. and Four p.m. (Saturdays Ten a.m. and Twelve noon).

Tenders enclosed in sealed envelopes addressed to The CLERK OF THE BOARD, Metropolitan Water Board, South Place, Finsbury Pavement, E.C. 2, and endorsed "Tender for Centrifugal Pumps, Shooters Hill," must be delivered at the Offices of the Board not later than Ten a.m. on 10th November, 1919.

A. B. PILLING,
2, South Place, Clerk of the Board.
Finsbury Pavement, E.C. 2.
25th September, 1919. A 720

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The Services are Required of

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Commencing salary £250 per annum.

Applications on foolscap paper, stating age, full qualifications and experience, and giving copies of not more than three testimonials, should reach the PRINCIPAL on or before Saturday, October 18th.

JOHN J. JACKSON, B.A.,
Director of Education.

City Hall,
Cardiff. A 726

THE TECHNICAL COLLEGE, LOUGHBOROUGH.

H. SCHOFIELD, M.B.E., B.Sc. (Hons.), London, A.R.C.Sc. (London), Principal.

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LECTURER in Automobile Engineering. Applicants should possess a University degree or its equivalent.

Salary £350, rising by increments of £25 per annum to £450.

Any further details, and forms of application, may be obtained from the Principal, to whom applications should be returned not later than October 14th, 1919. A 689

W. A. BROCKINGTON,
Director of Education.

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Applicants must have had a thorough Mechanical and Electrical training and be experienced in modern 3-phase and Boiler House Plant, Testing and Control of Labour.

Will be required to take charge of all maintenance work, and be generally responsible to the Chief Engineer for the efficient running of the plant and organization of the works.

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Apply, stating age, if married or single, giving full details of experience, training, when duties can be commenced, and accompanied by copies of not more than three recent testimonials to

BOROUGH ELECTRICAL ENGINEER,
Suffolk Road, A 746
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BRADFORD EDUCATION COMMITTEE.

TECHNICAL COLLEGE.

Department of Mechanical and Civil Engineering.

Applications are Invited for

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16th Sept., 1919. BY ORDER.
A 481

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MUNICIPAL TECHNICAL INSTITUTE, Romford Road, Stratford, E. 15.

Applications are Invited for

the following POSTS :—

CHIEF LECTURER in Electrical Engineering; salary (including War bonus) £300 per annum, rising by annual increments of £10 to a maximum of £450 per annum.

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The present rate of War bonus is £50 per annum.

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Applications, with copies of recent testimonials, should be sent to the PRINCIPAL, Municipal Technical Institute, Romford Road, Stratford, E. 15, not later than 14th October, 1919.

GEORGE R. HILLEARY,
Education Department, Town Clerk.
95, The Grove, E. 15.
25th September, 1919. A 721

ENGINEERING & TRADE SCHOOL, LEYTON.

Applications are Invited for

the POST of INSTRUCTOR in Workshop Practice in the Junior Technical School. Candidates should have had recent experience in machine shop practice and will be expected to assist in some of the Laboratory Classes. Initial salary from £180 to £220 according to qualifications, &c.—For forms of application, which should be returned as soon as possible, send stamped addressed envelope to

R. DEMPSEY,
Clerk to the Governors.
Town Hall, Leyton. A 552

CITY AND GUILDS (Engineering) COLLEGE.

The Delegacy of the College invite

Applications for the Post of

WORKSHOP INSTRUCTOR in Electrical Engineering. Salary £180, with special bonus for the present at the rate of £100.

Applications, giving full particulars of age, training and experience, with testimonials or references, should be addressed to Professor T. MAHER, F.R.S., City and Guilds (Engineering) College, Exhibition Road, London, S.W. 7. Ex-Service man preferred. A 730

ENGINEERING & TRADE SCHOOL, LEYTON.

Applications are Invited for

the POST of TEACHER of Engineering Subjects in the Junior Technical School. Candidates should hold a University degree in Engineering or equivalent qualifications, and have had workshop and drawing office experience. Previous teaching and electrical laboratory experience desirable. Initial salary £190 to £240 rising to £350, according to qualifications.

Form of application may be obtained from R. DEMPSEY, Clerk to the Governors, Town Hall, Leyton, and should be returned as soon as possible. A 551

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LECTURE on Elementary Engineering subjects and to assist in the Testing Laboratory at Faraday House. Commencing salary £250 per annum.—Write to the PRINCIPAL, Faraday House, Southampton Row, W.C. 1, and state when free to begin duties. A 741

Teacher.—Wanted, at the

L.C.C. SCHOOL of ENGINEERING and NAVIGATION, POPLAR, VISITING TEACHER of BOILERMAKING for two evenings a week at a fee of 15s. an attendance.

Candidates must have a thorough knowledge of the theory and geometry of the subject. Trade experience essential. Preference will be given to persons who have served or attempted to serve with the forces of the Crown.

Application forms may be obtained from the Education Officer (T.), Education Offices, Victoria Embankment, W.C. 2 (stamped addressed foolscap envelope necessary). Form must be returned by Eleven a.m. on 10th October, 1919.

Canvassing disqualifies. A 686

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REQUIRED for Reinforced Concrete Construction in the East, for three years with possible extension. Salary £600 per annum. Free passage. Candidates having wide experience of building generally and particularly reinforced concrete construction, should apply at once by letter, stating age, full details of experience and earliest date prepared to sail, to "L," Box 517, T. B. Browne's Advertising Offices, 163, Queen Victoria Street, E.C. 4. A 688

Machine Shop Superintendent

WANTED for large machine shops, 700 machines. Must be a first-class man, and have held a similar position with up-to-date firm; medium and heavy work. State full particulars, age, present employ, salary, which will be treated in strict confidence.—Address, A 653, Offices of Engineering.

Fitting and Erecting Shop

SUPERINTENDENT WANTED. Must be first-class man, with wide experience in control of large number of men and up-to-date factory experience. Marine experience an advantage but not absolutely necessary. State age, full particulars, present employ, salary, which will be treated in strict confidence. — Address, A 652, Offices of Engineering.

Supernumerary Assistant

LOCOMOTIVE SUPERINTENDENT REQUIRED by the Government of Nigeria for One Tour of 12 months' Residential service, with possible extension. Salary £350—£10—£400, and a War bonus of £120 a year, which will be continued until six months after the restoration of peace and will then be reconsidered. Free quarters and first class passages. Liberal leave in England on full salary.—Candidates, age about 25, preferably graduates of the Institution of Mechanical Engineers, who have served apprenticeship or pupilage in the Locomotive Department of a British Railway, and have had some experience in the running department, preferably in a responsible position, should apply at once (by letter), giving brief details of age and experience to the CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W. 1, quoting reference M/Nigeria 8091. A 713

Assistant Storekeeper

REQUIRED for the Nigerian Government Railway. Open lines, for one tour of twelve months' service with possible extension. Salary £350-£10-£300 and a War Bonus of £120 per annum which will be continued until six months after the restoration of peace and will then be reconsidered. Single quarters. Free first-class passages. Liberal leave in England on full salary. — Candidates, aged 25-35, who have had experience in a Locomotive Sub-store, should apply at once (by letter) giving brief details of age and experience to the CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W. 1, Quoting M/8788. A 712

Manager for Engineering

Works in Calcutta WANTED, must have thorough experience in ship repairs and general engineering. Salary Rs. 1000 per month and commission.—Apply, stating age, experience and qualifications, to BOX M 725, Lee & Nightingale, Advt. Offices, Liverpool. A 417

THE IRON AND STEEL INSTITUTE.

(*Concluded from page* 406.)

Synthetic Cast-Iron.

The first paper taken at the meeting on Friday, the 19th inst., was one on "Synthetic Cast-Iron," by Mr. C. A. Keller, Livet, France. It was read in abstract by the secretary. We intend to print it in full in a future issue.

In opening the discussion, the chairman, Sir Robert Hadfield, said the paper was interesting, but added he could not himself quite see the object of turning steel into cast-iron and turning this back to steel again. Of course, during the war there had been a special object in doing that. In any case, the paper was a most valuable and interesting one and indicated how the difficulties of such a situation could be met. No doubt, the author's method had been of great assistance during the war.

Dr. Stead stated he had had some little experience in the production of synthetic cast-iron in England especially for motor car and aeroplane cylinders. He had proceeded in about the same way as the author, and had come to the conclusion that but for the cost the production of synthetic cast-iron in the electric furnace was a most delightful one, especially to the chemist, who could build up anything and make the analyses exactly as he required. The details in the paper were very valuable and interesting, and were hints for those who wished to make synthetic iron. But he quite agreed with the chairman that the making of iron synthetically and turning it back to steel again would not appeal to the average metallurgist. The whole question was one of cost, and unless enormous water power was available and current could be obtained at low cost the scheme could not be considered a practical one, in this country at any rate.

A hearty vote of thanks was accorded the author for his communication.

The Action of Iron Oxides upon the Acid Furnace Structure.

The next paper taken was the one having the above title, by Mr. J. H. Whiteley and Mr. A. F. Hallimend, M.A. It was read in abstract by the former and we propose to reproduce it in a forthcoming issue. It reviews the sources of the materials which accumulate in the chambers; the corrosion of the furnace lining; of ports and uptakes; the chequer work; and gives microsections of drips containing silica and the oxides of iron.

The discussion was opened by Mr. Cosmo Johns who, as a member of No. 1 Committee, desired to thank the authors for their most valuable paper. The numerous facts and most interesting observations recorded will be of great value to those who are striving to improve the qualities of the silica refractories. It was very necessary that this work should be carried further, and he (the speaker) hoped that it would be possible for the authors to continue their researches. As to the origin of the iron oxide found in used silica bricks, he (the speaker) thought that the iron vapour theory most completely explained the facts, though other factors might be present. It was difficult to discuss the reactions between the iron oxides and silica at high temperatures, owing to our very limited knowledge of the constitution of the oxides of iron under varying partial pressures of oxygen. He had found that at the temperature at which pure silica softened magnetite was insoluble in it. When a stream of steel was pouring over the end of a trough why, he asked, was it not oxidised. It was, he thought, because there was iron vapour round it. Why should that iron vapour be given off only during the boil in the furnace? The authors had not tackled that difficult question, which certainly should be investigated. Nobody seemed to think about it at all and the Universities had quite neglected it.

Dr. Stead had had occasion to examine a silica brick from the top of a basic open-hearth furnace, and it had been suggested at a discussion on the subject before the Ceramic Society that the fluxing of the brick was more due to the projection from the basic slag than to the floating dust. He thought both were responsible for the corrosion. It had been suggested also that many observers had found that a considerable quantity of phosphoric acid was in the lower end of the brick, the hot end where it had been melting away. This indicated that the source was a projection of basic slag from the furnace. The analysis, however, showed that very little of the basic slag had been projected into that particular brick. It was interesting as showing that in a brick from the roof of a Talbot furnace so little of the fluxing was due to projection.

Professor Louis thought the authors had proved conclusively that the oxide of iron came mainly during the boil. He was not altogether prepared to accept the possibility of iron vapour being formed, but would like some one to investigate whether it might not be due to the formation of iron carbonyl. This might meet the point which Mr. Cosmo Johns had raised.

Mr. E. H. Saniter said there was no doubt but that the stream coming from the furnace was surrounded by something, whether vaporised iron or vaporised oxide of iron. It seemed to him impossible to realise that the oxide of iron could get into that very fine state and condition, without the iron being preliminarily vaporised. When one saw the brown fumes rising off the surface of the bath, one could only suppose these were due to the vaporisation of the iron in direct contact with oxygen. He appreciated the paper greatly; the authors were doing very valuable work in elucidating those points in connection with the open-hearth furnace.

Dr. Hatfield agreed with Professor Louis that one matter to be considered was the possibility of the formation of carbonyl. He did not agree with Mr. Cosmo Johns and Mr. Saniter in regard to the vaporisation of the iron. In watching the stream of metal, one became convinced that it was largely the gases in solution which came off and protected the stream.

Professor Benedicks, in connection with Mr. Cosmo Johns' suggestion remembered the old saying that "atoms had their own little atmospheres." One could assume that iron had an atmosphere around it, but whether that would explain the reason why the iron did not get oxidised was another question. He thought nitrogen would be the protecting agent in teeming the steel.

Mr. W. Savage asked whether the oxidation referred to by the authors was noted from the period when the furnace was first started, for it was known to those engaged in acid working that the best steel seemed to be obtained when the furnace was about half worn out.

After a brief reply by both the authors, they were heartily thanked by the meeting for their interesting work.

On The Woody Structures of Fractures of Transverse Test-Pieces taken from certain Special Steels.

The third paper taken on Friday 19th was that having the above title, contributed by Mr. J. J. Cohade, of Crensot. We shall reproduce it in a later issue. It was read in abstract by the secretary. We need not abstract it at this stage, the discussion, recorded below, indicates its scope. It was taken in conjunction with a contribution, by Mr. A. M. Portevin, Paris, entitled

Notes on Defective Fractures in Tensile Test-Pieces during the Inspection of Gun Parts.

In opening the discussion, the chairman said the institute was much indebted to Mr. Cohade for his very valuable paper. He hoped Mr. Cohade would give a little more information about the temperature of the baths used in producing the steels. The temperature of the baths and the casting temperature had much influence upon the quality of materials of the kind, which had to be submitted to transverse tests.

Mr. Saniter said Mr. Cohade's paper gave a good deal of information on a subject that was little known to the general steel maker. He agreed to a large extent with the reasons given for breaking with a woody fracture. Those reasons to his (the speaker's) mind were not the cause of the "woody structure." The woody structure was in all the steels. It might be the cause of their breaking, just as a notch in a bar would cause it to break. On etching the steels with a copper reagent, in all cases it would be found that the woody, fibrous structure was obtained; it was due to the drawing out of the dendrites in the steel into fibres. It was characteristic that only those which did not elongate broke with the woody structure, whilst those which did elongate broke with a fibrous structure; the difference was entirely due to the mechanical work of fracture. The inclusions and the tiny blowholes which might not have been welded up were a fruitful source for causing steel to break short. Also it was generally held that working beyond a certain point made it more difficult to avoid a woody fracture. He (the speaker) thought there was no doubt also that as there was a great difference between the dendrites and the matter between them, in many cases that was a cause for getting a woody fracture instead of a fibrous one. But another cause of the steel breaking in that manner was the state of strain in the steel, this having nothing to do with inclusions or chemical composition. Two or three years ago, he cut a slab off a round bar of nickel steel about 7 in. diameter. He made a dozen bending tests from the slab, marked 1 to 12. The odd numbers were bent as cut from the bar and the even ones treated in oil at 250 deg. C. for one hour and allowed to cool in the oil. All the benders which had not received treatment broke and all the treated ones stood, He maintained that a treatment at such a low temperature as 250 deg. on a steel which had already been tempered at over 600 deg. did not affect the structure as such in any way. The only reason for the difference must have been the release of the strain in the steel.

Dr. Hatfield also congratulated Mr. Cohade and said that all those who had had experience of the cross tests during the war must agree with his conclusions. The most important item to his (the speaker's) mind was the presence of non-metallic inclusions, and the chairman in speaking of the temperature of casting was getting at the root of the whole trouble. By taking care in the finishing of the steel in the furnace, if a slight acidity was introduced into the slag on the lines of the experiment he (the speaker) had carried out a few years ago, then a set of conditions was obtained yielding steel with a minimum of inclusions. He asked whether Mr. Cohade added the special elements in the ladle or in the furnace? (Mr. Cohade replied in the furnace, and added that he waited 40 to 60 minutes before casting.) (The chairman enquired what was the temperature of the steel and Mr. Cohade replied, the highest possible.) In regard to Mr. Portevin's paper, its author emphasised the presence of ferrite in the inclusion; if the steel was hardened that soft material round the slag inclusion disappeared. Further, in regard to Mr. Cohade's paper, Dr. Hatfield stated that the real cause of the woody structure was the lack of homogeneity introduced into the structure by the presence of the slag-forming areas of the author's description. Nickel steel or nickel-chrome steel, etched and looked at under not a high but a low magnification, showed a streaky structure; the slag inclusions formed seats for the local segregation which caused the streaks.

Professor Giolitti said that to his mind the effect of inclusions was not due specially to the inclusion in itself but to the action of the inclusions on the surrounding metal. That might be ascertained in the case of inclusions of sufficient dimensions to be seen under the microscope. His own experiments of the treatment in reducing and oxidising gases of small samples of metal containing inclusions showed that the effect of the inclusions was specially due to the ferrite forming round them. When the metal was at the forging temperature a special condition of equilibrium would be established in the gases in solution in the inclusion. When the temperature altered, those conditions were not the same, and in some cases, the gases in solution in the inclusion acquired an oxidising action on the metal surrounding it. That explained the formation of a decarbonised zone round the inclusion, and also that in several instances in the woody metal it was not possible to see any inclusion. Dr. Stead having asked Professor Giolitti if his idea was that the inclusion itself absorbed gases, Professor Giolitti replied in the affirmative, adding

that there were two atmospheres of gas, one in solution in the inclusion and one outside the inclusion.

Mr. A. G. Service congratulated Mr. Cohade for putting forward the difficulties which nickel-chromium steel manufacturers and gun makers in particular were up against. The author gave four reasons for the origin of the streaks:—1. Presence of non-metallic inclusions; 2. Tiny blow-holes; 3. Chemical composition of the metal; 4. Overworking. There was considerable evidence for these reasons, except the third which he did not think the author had proved. The chemical composition did not play a very important part in the matter. He (the speaker) had had trouble with inclusions, but he had increased the carbon content from 0·46 to 0·50 per cent., and he found less inclusions and less woody fractures. One could get a woody fracture in ordinary carbon steel. The difficulty was just as pronounced in steel having 0·28 carbon and a comparatively high percentage of manganese as in nickel-chrome steel. He (the speaker) had paid attention to the temperature, and a high temperature was wanted in the furnace, besides carefully watching the slag during the working of the charge. The slag had to be very fluid during the boiling period. The casting temperature was difficult to measure, but that could be ascertained, and teeming in the ladle at 1500 deg. C. gave him good metal, whilst teeming in the ladle at 1560 deg. C. gave him the cleanest nickel-chromium steel he had ever had. The matter was more of a melting shop question; the working up question came in the second place. If, however, the metal was worked up at 900 deg. C. there was more difficulty than at a higher temperature. The method to be followed was to get a high temperature in the furnace, a proper slag and a suitably high forging temperature.

Mr. Cosmo Johns, who followed, said he thought he could hardly venture to make any comments. He had commenced manufacturing nickel-chromium steel as early as over twenty years ago in large quantities and, notwithstanding, he felt he could not speak dogmatically on the subject. Metallographists rarely said how the points dealt with came about; they left it to the steel maker. Professor Giolitti had thrown out valuable suggestions which came nearer to explain the cause of the difficulties referred to than the suggestions put forward by most theoretical men. He (the speaker) agreed with Mr. Service and Mr. Cohade as to the desirability of having a high temperature in the furnace; the reactions there could only be had at a high temperature, and these castings should also be done at a high temperature with a correct rate of teeming. Cracks would occur if too many heat units were poured in per size of mould and there was a casting speed that should not be exceeded. He (the speaker) here referred to a short paper he read before the Chemical Society on April 30, in which he discussed the oxygen compound found in steel. Mushet had said that pure steel contained no oxygen. All difficulties in all steels was due to the presence of an oxide, and these oxides in solid or gaseous solutions destroyed the continuity of the metal. In that paper he offered explanations, and it did not receive the attention which he thought it deserved; in it, he believed, would be found the basis of the whole thing. With care and time steel could be produced without inclusions; it was, however, a very difficult matter, many had tried and had not succeeded.

Dr. Head stated that there was scarcely a maker who had not sent him at one time or another woody fractures. He had been troubled to find an explanation of the problem; sometimes there were slag inclusions and at other times these were so fine that they could not be seen with the microscope. There were in woody fractures an infinitesimal amount of non-metallic inclusions. In working up a piece at a high temperature the slag inclusion elongated together with the metal and there was still the same trouble. If the inclusion were very fine, at a high temperature welding would take place. All should read Mr. Cosmo Johns' paper (alluded to above) as it gave an explanation from the point of view of a metallurgist.

Mr. Dickenson showed on the blackboard a sketch and pointed out the occurrence of crystals divided by non-metallic impurities, the formation of planes of weakness and the greater danger of the difficulties occurring as the crystals became smaller by the working up. The small crystals were of the worst possible type. He confirmed the desirability of a high casting temperature after proper treatment in the furnace.

Dr. F. Rogers, after a few remarks on Mr. Perterin's method compared with his own, referred to Mr. Cohade's statement to the effect that the casts from the acid open-hearth made with all precautions observed in gun manufacture, much slower working of the charge, charging in several relays, &c., gave excellent results, and said he thought those results were due to high temperature. He thought also that occurrence of woody fractures in nickel-chromium steel were not primarily due to inclusions, the dendritic structure alone was often a sufficient explanation of them. He showed on the blackboard a stepped fracture and pointed out the directions of the dendrites.

Dr. Rosenhain said his feeling on reading Mr. Cohade's paper was that the best results were obtained by maintaining the steel at a high temperature for the longest possible time. The dendritic structure must play an important part in the fracture of material. By annealing large pieces at a high temperature it might be that woody fractures were got rid of at too high a price, and it was desirable to carry out this "heat treatment" before forging commenced. He might add that he had made experiments for eliminating the lines developed in woody fractures by high annealing which got rid of the dendrites.

Mr. Cohade intimated his desire to reply to the discussion in writing, and on the motion of the chairman was accorded a hearty vote of thanks for his paper.

Nickel-Chrome Forgings.

The first paper taken on the afternoon of Friday, the 19th, when Dr. Head occupied the chair, was the one on "Nickel-Chrome Forgings," by Mr. J. H. Andrew, D.Sc., Mr. J. N. Greenwood, M.Sc., and Mr. G. W. Green, of the Metallurgical Research Department of Sir W. G. Armstrong, Whitworth and Co., Limited, Openshaw. It was read in abstract by Mr. Andrew, who stated that the source of trouble with such forgings was traceable to the casting, and added that the metal should be run into the mould as cold as possible, but a high ladle temperature was advantageous in helping to cleanse the metal. What was wanted was a ladle stopper which did not stick when the metal was kept in the ladle for a time. The paper dealt exhaustively with the casting and the forging of ingots and with tests of all classes during the various processes.

Brittleness in Nickel-Chrome and Other Steels.

This paper was then taken and was read in abstract by its author, Dr. A. Rogers, who illustrated it at the meeting with a number of diagrams. It was not ready in time for publication in its complete form, and the author added that he proposed to submit the full paper at the next spring meeting.

Temper-Brittleness of Nickel-Chrome Steel.

Mr. R. M. Greaves, M.Sc., F.I.C., Woolwich, read in abstract his paper on "Temper-Brittleness of Nickel-Chrome Steel," which contained a further communication by himself, Miss Muriel Fell, B.Sc., Woolwich, and Sir Robert Hadfield. These papers, which we publish in full in the present issue, give the comparative test figures of steels of varying composition and deal with the effect of the heat treatment on the test figures.

Some Experiments on Nickel Steel.

The three papers named above were taken for discussion together with one by Major N. Hudson, D.S.O., R.A., on "Some Experiments on Nickel Steel," which was read in abstract by the secretary. Major Hudson's conclusions are that carbon monoxide will combine with the nickel in a nickel steel even in the case of steel of a fairly low-nickel content. The most favourable conditions, as far as can be ascertained in his few experiments, for the formation of the carbonyl appear to be:—Low temperatures, freshly machined metal, and large surface area exposed. As nickel steel is sometimes used in positions where it is liable to exposure to carbon monoxide gas at varying conditions of temperature and pressure, the question of the removal of nickel from its surface in the form of nickel carbonyl may have some practical bearing on such questions as the investigation of erosion, &c.

The chairman, Dr. Head, said that this was the first time in the history of the Institute that a lady's name appeared as contributing to the proceedings, and he tendered his congratulations to Miss Fell. Dr. Andrew had stated in his paper that nickel, chromium and manganese appear to make but little difference to the manner of solidification of the steel. It occurred to Dr. Stead that in the diagram the liquidus and solidus were close together all through, that being what one should expect.

Mr. M. M. Ashdown asked for complementary information. The paper by Dr. Andrew gave in Table I the casting time but did not state whether the time was in seconds per ton or in minutes per ingot. In regard to the slower and quicker rate of casting two ingots referred to (5-11 B and 5-11 C) the contraction of the skins played a part. Referring to Dr. Andrew's remarks as to the outstanding feature of his Table I, namely, the very definite improvement made in the 22-ton ingots, and particularly in the 11-ton ones over the 45-ton, this was as all could expect. But the author was nearer correct in his summary, where he stated that the larger the ingot the greater the segregation owing to slower cooling of solidification, and added that whereas the 22-ton ingot showed signs of secondary piping and the 11-ton had unsound metal right down to the bottom, the 45-ton ingot was sound, the author further saying that this could only be due to the fact that the 45-ton ingot was cast wide end up, whereas the 22-ton and 11-ton ingots were cast narrow end up. The author had given in two tables the analyses of two ingot heads; these results were worthy of more thought and were misrepresentative, since the sketches showed the segregates running right to the outside of the ingot heads. The author's analyses showed differences in the percentages of phosphorus and sulphur, and it was hardly feasible that he had "dodged" all those segregated areas. In recommending the tun-dish, he thought the author had been led away by the success the tun-dish had for small sized ingots. The author had also stated that there appeared to be no advantage in allowing the ingot to cool previous to reheating; he (the speaker) thought it advantageous to allow the ingot to fall to a dull red heat before reheating. One of the author's conclusions was that annealing previous to oil-hardening and tempering neither improved the mechanical test nor facilitated machining; if this was proved, a large amount of fuel was being used to no purpose. Some of the author's illustrations of piped ingots pointed to a practice which was not the usual, or to the use of unsuitable ingot moulds. It was not advisable for many reasons to transfer heavy ingots, as soon as possible after casting to a soaking pit, contrarily to what the author had proposed. Referring to Mr. Greave's paper, Mr. Ashdown was sorry the author did not include impact tests on air-cooled specimens; it was not always convenient to water-quench. Mr. Greaves had stated dogmatically that reheating to a temperature in the neighbourhood of 520 deg. C. resulted in brittleness, whatever be the subsequent rate of cooling; that was open to much discussion. He (the speaker) had produced at Elswick, steel, air cooled, giving yield 57·5 tons; maximum load, 63·6 tons; elongation, 18 per cent; reduction of area, 54·7 per cent.; impact test, 46·8, these being the average results of 100 consecutive tests. Mr. Greaves had also said that brittle steel could be restored by reheating to between 600 and 670 deg. C. and cooling rapidly. But badly ore heated steel could not be restored in that fashion. Finally, Mr. Ashdown stated that every forging, air-cooled complied with the impact test conditions; water did not give better results. Mr. Greaves' steel was somewhat high in sulphur, while that in Sir Robert Hadfield's communication was rather high in phosphorus.

Mr. Dickenson found that the discussion which had been held in the morning dealt with practically

all the ground covered by Dr. Andrew's paper. Mr. Greaves' was the first publication on the subject, although much had been imparted confidentially by the Air Board. It was important that the results should be brought forward, and Mr. Greave had done that well. This paper was a suitable rejoinder to those who cast doubts on the value of the single-blow impact test. Mr. Greaves' results generally confirmed those of the speaker, obtained on somewhat similar lines, although the author had not emphasised strongly enough the important fact that temper-brittleness was easier to have in some samples than in others. He showed on a blackboard the behaviour of steels when water-cooled and air-cooled, in regard to impact, of Brinell hardness figures.

Mr. J. C. W. Humfrey stated that the macro-prints in Dr. Andrew's paper greatly interested him, and the author's results in many ways confirmed his own. One point, he thought, had not been made quite clear, in regard to the dendritic and non-dendritic structure; in his experience the branch form was always present. Macro-prints suffered from reproduction, but upon examination of the originals it would be found that the dendritic form was always present. Dr. Andrew had said that the stability of the original dendritic structure was remarkable, and emphasised the point that this was due to the separation or segregation of the impure from the pure material at the time of casting or, rather, at the time of solidification of the steel. He (the speaker) was not at all clear as to what the author meant. The hair cracks were, Mr. Humfrey added, a constant source of trouble, and no proper explanation was forthcoming as to when they were formed or how they were formed. It was impossible to discuss Dr. Rogers' paper until there were further data. Mr. Greaves' paper was a most interesting one. In this, reference should be made to the type of fracture.

Dr. Rosenhain said that statements to the effect that a fracture was inter-crystalline had to be taken with great reserve, for there was something weak and brittle between the crystals.

Mr. E. H. Saniter stated he had marked the same paragraph in Dr. Andrew's paper which Mr. Humfrey could not understand; he was also at a loss in regard to the author's point and asked for more data. Dr. Rogers had given a list of the steels which he said were subject to temper-brittleness; he (the speaker) had not met with temper-brittleness in nickel steel and nickel-chromium steel. Dr. Rogers had also said that carbon steel containing from 0·2 to 0·4 per cent. was subject to brittleness; he would be glad to know whether that could be got rid of by treatment of the steel.

Dr. Hadfield took exception to Dr. Andrew's statements in regard to the dendritic structure and its effects, and emphasised the action played by the drawing out of the crystals. Dr. Rogers had put forward a number of theoretical points which were not supported by practical experience. It was necessary to know also how the redescence curves shown at the meeting had been prepared, and if critical points existed where shown, to know by what they were due. In regard to Mr. Greaves' paper, Dr. Hadfield emphasised the necessity of carrying out a whole series of different mechanical tests, since all the phenomena which occurred with steel could not generally be disclosed by one test taken alone, and only so far as the ultimate service condition was revealed, only so far was the test of importance.

Dr. L. Aitchison criticised several of Dr. Andrew's test figures of the steel in the cast and in the forged form. The author's method of taking the macro structures formed a good precedent to follow. He would have liked the author to give more information on the hair cracks, and asked whether he looked upon them as harmless or whether he eliminated them. With reference to Mr. Greaves' paper, the nickel-chromium steels did not all show temper-brittleness; he thought it was treading on very thin ice when saying that temper-brittle steel showed inter-crystalline fracture, for in tests the steel did not break between the crystals or "grains" but through them.

Mr. H. Moore said that nickel-chromium steel was a most valuable steel, if one knew how to get rid of temper-brittleness. Most makers had trouble with hair-line cracks, and he was sorry Dr. Andrew did not deal exhaustively with those cracks. Casting at a low temperature was contrary to the practice of most makers. Dr. Rogers' paper, he thought, suffered from undue compression. In regard to differences in the Brinell number of one specimen quenched and another slowly cooled, the explanation was that the latter had the longer tempering.

The authors expressed their wish to reply to the discussion by correspondence. They received the cordial thanks of the meeting for their contributions.

The usual thanks of the Institute to the Institution of Civil Engineers for the loan of their hall, and those of the members to the chairman completed the proceedings.

THE PHENOMENA OF DRYING WOOD.

Long familiarity with certain technical operations in the preparation of raw materials inclines us often to ignore the complicated processes at work, effecting changes in the character and composition of the material treated. This commonplace is illustrated in the process of wood drying, of which little exact knowledge exists as to the chemical and physical changes wrought by the removal of water, as the timber passes from the green condition to the perfectly dry state. Even when untoward results make their appearance they are accepted as inevitable, and little trouble is taken to trace the causes, or to understand the manner in which a very complicated structure would behave under the conditions to which it has been submitted. The evaporation of water from wood by the application of heat is by no means a simple operation. Mechanical stresses are set up by the unequal manner in which the water passes from the centre to the surface, and it is the effect of these stresses that is frequently overlooked or misapprehended. The origin of these tensions and compressions may not be followed with exactness, for it is not known definitely how the water makes its escape. More than one cause may be in operation varying in different trees, according as the form and arrangement of the cells favour capillary action, or possibly promote repeated evaporation and condensation. Fortunately, it is not necessary to decide such troublesome questions in tracing the effect of internal stresses accompanying the transfusion of moisture. At least this is the view of Mr. H. D. Tiemann, dry kiln specialist, United States Forest Service, who has discussed* the behaviour of timber at certain stages of its drying, demonstrating the origin of many imperfections, and directing attention to much experience gained in the Forest Products Laboratory, Madison, Wisconsin.

Timber in its green state, as is very well known, will contain water in two forms. In the cavities of the cells, or pores, moisture will collect as free water and also, absorbed in the substance of the wood itself, hygroscopic or "imbibed" water will be found. As a rule, the free water may be evaporated without any shrinkage or deterioration of the wood. In some trees, however, the evaporation of the free water seems to be sufficient to cause a collapse of the cell walls, and this collapse is assisted if the wood is dried at too high a temperature. Frequently, however, the free water can be removed by heating above the boiling-point without injury to the wood, but if it is necessary to have recourse to gradual transfusion of the moisture through the cell walls, instead of actual boiling, a great difficulty can arise. The surface may be dried below "the fibre saturation point," or that point at which the cell walls, or wood substance, are completely saturated, and if this point in the drying is reached while free water remains in the interior, trouble will ensue. The "fibre saturation point," a very critical point in the drying, lies generally, with the exception of the oak, eucalyptus, and a few other trees, between moisture condition of 25 per cent. and 30 per cent. of the dry weight of the wood.

The effect of the removal of the hygroscopic water is very different. Shrinkage and other changes

Fig. 1. Badly Honeycombed Oak Wagon Felloes Produced by Too-Rapid Case-Hardening in Drying.

* "*The Phenomena of Drying Wood*," by Harry D. Tiemann, M.E., M.F., Journal of the Franklin Institute, July, 1919.

take place, which set up stresses in the timber, often attended with detrimental results. In order that this absorbed water may pass from the interior of a beam, the main portion must pass transversely from cell to cell and evaporate at the surface. This process of transfusion in the case of air-dried wood is tediously slow. Inch planks, according to the material, will require from six months to three years, under favourable conditions of atmosphere, piling, &c. Even under the best circumstances, the wood will rarely dry below 12 per cent. to 14 per cent., and to obtain a thoroughly dry wood, kiln-drying must be employed. With kiln-drying the effects of unequal shrinkage are more manifest, for the higher the temperature under moist conditions the greater the shrinkage. Moreover, wood substance, when moist, becomes soft and plastic if submitted to high temperatures. Cohesion between the fibres easily breaks down, and collapse of cells may occur in some species. These are drawbacks inevitable in kiln-drying, which have to be met practically by skill and experience in the management of the kiln. Some of the effects are well known under the descriptions of "honeycombing," "warping," "washboarding," &c. Fig. 1, page 433, illustrates the effect of "honeycombing," due to severe "case-hardening" in drying. The origin of some of the less evident weaknesses is, however, traceable to more subtle causes such as internal stresses, due inherently to wood structure and may well be submitted to closer examination.

The term "case-hardening" adopted probably from the technology of metal tempering, may fairly well describe the condition of wood, in which the outside fibres have been hardened by shrinking through drying below the fibre saturation point, while the inner portion still remains moist. But the processes have little relation to each other. In the case of wood, owing to unequal shrinkage, internal stresses will be set up that will exercise a permanent or temporary effect depending upon the relative degree of hardening of the outer and inner fibres, and the relative amount of residual shrinkage when the timber becomes uniformly dry. It is easy to follow the general character of the mechanical action, though quantitatively the effect will vary with the moisture of the wood, the degree of shrinkage and the period in the drying operation at which the fibres become hardened or set. Temperature and the method of its application will be important factors, and as a rule the more rapid the drying the greater the case-hardening effect, and the greater the disturbing stresses.

On the application of heat, the general condition of kiln-drying as opposed to air drying, evidently the outer partially dried fibres shrink, while the interior of the mass is protected from undergoing any change, consequently the outer fibres must be in an abnormally distended condition. Owing to loss of moisture, these external fibres will become hardened in this distended condition to such an extent, that if we imagine this outer shell removed from the adherent internal portion, this hollow cylinder would not shrink down to its normal condition. While forming a solid block, however, the outer fibres are in tension and the inner in compression, but as the drying process advances, the inner portion begins to dry and will tend to contract through its normal amount. Such a degree of shrinkage is, however, impossible owing to the expanded condition of the outer ring of dry material. Consequently, a reversal of stresses will ensue, the inner fibres being in a state of tension and the outer of compression. If now the internal portion also hardens in this somewhat extended condition, approximate equilibrium will be established and the stresses disappear. Generally, however, in rapid drying the inner fibres remain in tension and the outer fibres are compressed, owing to the residual shrinkage of the outer fibre being insufficient to relieve the stresses. From this reasoning, it follows that pronounced case-hardened wood will shrink less than a similar block of wood dried in such a way as to permit the normal shrinkage of all the fibres. In other words, kiln-dried wood is on this ground less liable to shrink than air-dried.

If the stresses are of sufficient violence to overcome the cohesion of the material, a tendency to produce external cracking, or checking, will show itself in the outer fibres in the first stages of case-hardening, but after the reversal of the stresses, the internal fibres will tend to be pulled apart by these reversed stresses. The outer checks first produced will tend to close up "due to the compression stresses introduced in the external fibres by the subsequent shrinkage of the internal fibres. This condition of internal checking is commonly called "honeycombing."

Where case-hardening has not been sufficiently severe to produce fracture, its effects can be detected by experiment. Commonly a thin disc is cut across from a block of timber, and slots cut round the edge in the form of tuning forks. Such a slotted disc when cut through by a saw will indicate by the direction assumed by the prongs the condition of the stresses at the time the sample was taken, and also the nature of the residual shrinkages which may be expected to occur in subsequent drying. If the sample has been rapidly dried so as to produce case-hardening and the disc is cut when the outer surface is just dried below its fibre saturation tension, the outer surface will be stretched and the inner compressed. Under such conditions the prongs on the disc will bend outwardly when saw-cut. But at a later stage, or if the disc is further dried in the oven, these prongs will reverse their direction and bend inwardly because the external ring has already hardened somewhat in the expanded condition, so that its normal shrinkage is less than that of the inner side of the prongs. On the other hand, if the disc is cut after the reversal of the stresses, the outer prongs will tend to bend inwardly, and subsequent drying will only tend to increase the curvature. There must be an intermediate period when, if the trial disc be cut, the prongs will turn neither inwardly nor outwardly on the saw. But, nevertheless, when the disc is further dried the prongs will turn inwardly.

In air-drying, carefully conducted, case-hardening will scarcely be recognised, because the distribution of moisture throughout the mass is kept tolerably uniform during the entire process, and the stresses are therefore slight. When rapid drying is employed devices must be introduced to retard the rate of surface drying by maintaining a high humidity in the surrounding medium, but some case-hardening is inevitable, however carefully the operation is carried out. As shown in Fig. 2 the effect can be relieved or entirely reversed by subjecting the wood to steaming processes under slight pressure, when the outer fibres become soft and plastic.

Mr. Tiemann endeavours to give greater precision to the principles enunciated, by comparing the movement of consecutive layers, or strips, of wood in the block while drying, to that of a series of spiral springs under gradual increasing pressure, but this does not advance the subject very far. He cuts a disc transversely across a block, and divides a portion into eight narrow strips, each strip being supposed to act as a spiral spring whose ends are attached to two horizontal bars, so arranged as to remain always parallel. The stresses produced in these springs, by tightening nuts outside the horizontal bars or some such mechanism, are supposed to be directly proportional to the amounts they are stretched or compressed from their neutral position. The effect of drying the wood is to be regarded as equivalent to a shortening and not a compression of these springs. As an illustration by general analogy the suggested mechanism may prove useful, but as an aid to analysis the scheme breaks down, mainly from the difficulty of following mechanically the effect of the variables of which mention has been made. The involved processes going on in the timber are too intricate to be successfully imitated, or in the author's words "the analysis becomes too complicated to follow clearly," and some simplification has to be made. We are accustomed to similar expedients in purely mathematical analysis, and if that method had been adopted, the result would probably have been the same. The object in view is praiseworthy; it is to trace and determine the progressive variations of the stresses in contiguous strips, supposed to correspond in action with that of the spiral springs, and in this way to investigate the phenomena involved in drying wood from the outer surface inward, and the consequent successive case-hardening of the outer layers. The results are reproduced in a table which gives the shrinkage of the disc as a whole, and the relative stresses in each of eight strips. This table is very interesting as it goes far to explain many of the peculiarities met with in commercial practice, and especially the unexpected or anomalous behaviour of the prongs of the slotted test disc at different periods of the drying process to which attention has been called. Fortunately the main result can be put in a graphical form, Figs. 3 and 4. In these diagrams, tension is indicated by distances below the horizontal line, and compression by distances above. The ordinates show the comparative lengths by which the adjacent strips will be altered, if a disc be slotted in the condition under consideration. The combined area above the horizontal line is always made equal to the area below. The cases chosen for illustration are described as "largely empirical," but how far the results have been derived from actual experiment is not stated.

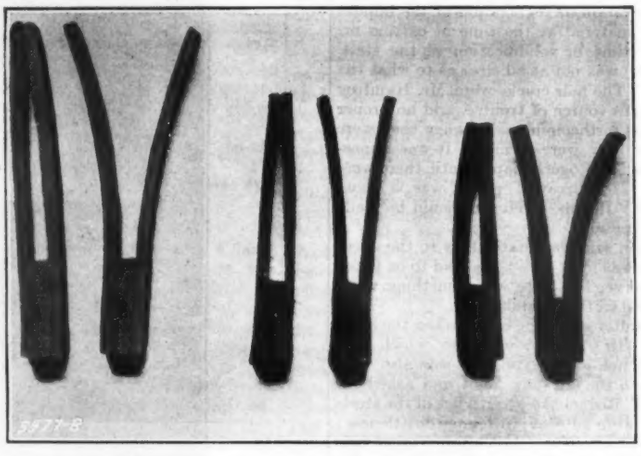


Fig. 2. Discs Cut from Case-Hardened Maple and Oak Boards. The Alternate Ones on the Left show the Condition of the Boards when First Dried; those on the Right show Reversal of Stresses after Steaming the same Boards at a Slight Pressure.

The diagrams fairly well tell their own tale. In case A, Fig. 3, case-hardening has not yet proceeded to an appreciable extent, but probably the maximum stresses are exhibited in this, the first stage in drying. The tension inside the block is necessarily less than at the surface. In this condition of maximum tension, if a disc be cut and slotted, the outer, partially dried, prongs, will bend

outwardly on the saw. If dried slowly, the prongs will become parallel again and all of the same length. Under condition B, Fig. 4, where strip No. 1 is swelled to full length and the remaining strips not altered, if a disc be similarly treated the outer prongs will have a tendency to bend inwards, but if the disc be given a single cut through the centre, the two prongs will bend outwardly. On further drying, however, the prongs in both cases will bend inwardly. In diagram F, a further stage in drying is represented, where case-hardening is well defined, and the effects noted in B are still further pronounced, while in G, a still later stage, with three strips "set," bending on the saw will occur if cut anywhere after the third strip. Further drying

Fig. 3. DIAGRAM SHOWING STRESSES IN WOOD WHILE DRYING UNDER CONDITIONS SHOWN IN MARGIN.

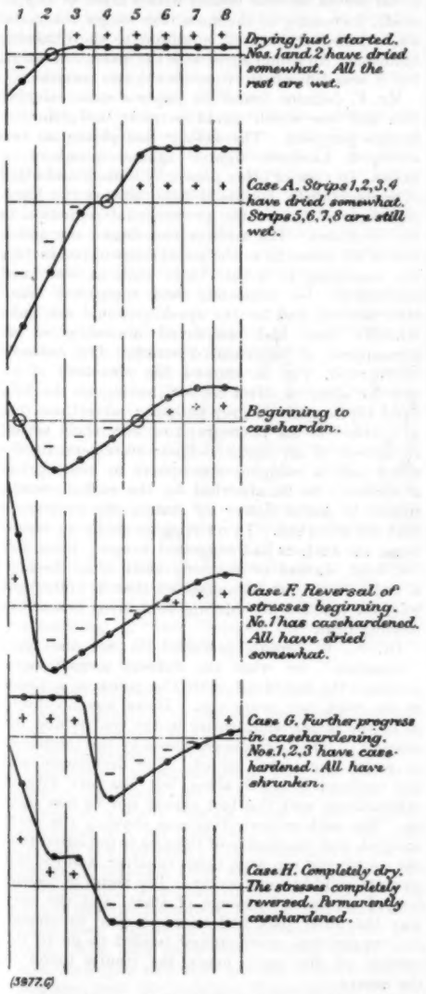
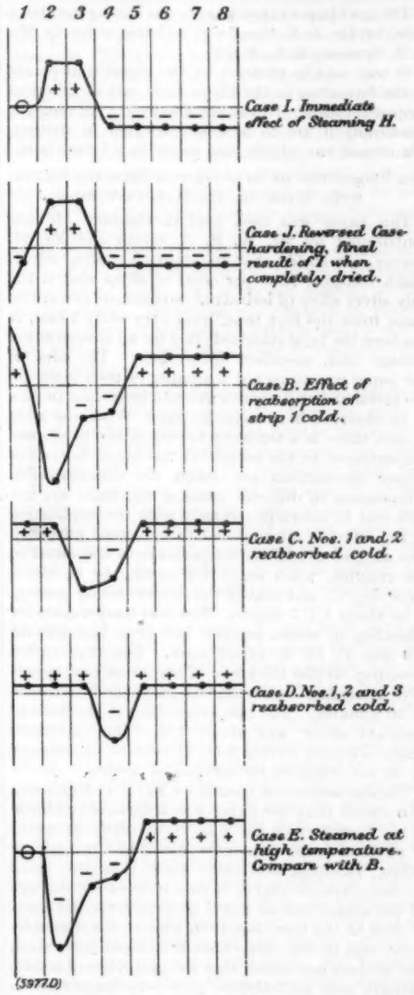

1 2 3 4 5 6 7 8
Drying just started. Nos. 1 and 2 have dried somewhat. All the rest are wet.
Case A. Strips 1, 2, 3, 4 have dried somewhat. Strips 5, 6, 7, 8 are still wet.
Beginning to caseharden.
Case F. Reversal of stresses beginning. No. 1 has casehardened. All have dried somewhat.
Case G. Further progress in casehardening. Nos. 1, 2, 3 have casehardened. All have shrunken.
Case H. Completely dry. The stresses completely reversed. Permanently casehardened.
(3977.C)

Fig. 4. DIAGRAM SHOWING STRESSES IN WOOD WHILE DRYING UNDER CONDITIONS SHOWN IN MARGIN.


1 2 3 4 5 6 7 8
Case I. Immediate effect of Steaming H.
Case J. Reversed Case-hardening. Final result of I when completely dried.
Case B. Effect of reabsorption of strip 1 cold.
Case C. Nos. 1 and 2 reabsorbed cold.
Case D. Nos. 1, 2 and 3 reabsorbed cold.
Case E. Steamed at high temperature. Compare with B.
(3977.D)

aggravates the binding effect. In case H, for example, representing a piece of completely dry wood, the outer prongs will bend on the saw and remain so. The inner prongs, 5 to 8, will remain straight.

These diagrams have also another value. They indicate what would be the probable effect of "steaming" at the various stages of drying and when such a process can be most advantageously applied. If timber in the condition shown in diagram A be steamed at a low temperature, or subjected to cool humid conditions, the outer portion will swell, having the effect at first of increasing the tension on the inner layers, a result to be avoided, as the tension would increase internal checking, or cause external checks to run deeper into the interior. With regard to the progress of tension inside a block, Mr. Tiemann suggests that "honeycombing" possibly starts initially with a small surface crack, which thence follows inwardly as the wave of tension moves towards the centre, much as a crack in a pane of glass will follow the progress of a comparatively slight stress, much less than that which would be necessary to initiate a crack in the unbroken pane. High-temperature steaming, diagram E, may be beneficial in relieving the ultimate case-hardening, and can certainly be applied advantageously after decided case-hardening has occurred. Generally when the outer layer is not softened at a low temperature, it will not crush under compression, and therefore no advantage accrues, because the case-hardening effects will reappear on subsequent drying. The steaming should be carried through at a sufficiently high temperature to render the timber plastic, so as to induce crushing in the outer layer, causing less resistance to be offered as subsequent drying proceeds. Steaming is most advantageously applied after the conditions represented in F have been attained, and reaches its maximum in the later stages as H: The compression stress can be completely eliminated from the layers affected if the temperature of the steam is sufficiently high (diagram I). If the steaming effect has not penetrated to all layers under compression stresses, a reversal of case-hardening will ensue as indicated in J, where if such a disc be slotted between strips 2 and 3 the outer prong will turn out slightly on the saw, while the strips 3 and 4 will turn inwards. Similar effects are noticeable under condition H. "If sawn in the middle, however, there is much less cupping in J than in H; in fact, it might easily be that the stresses are balanced so there would be no cupping at all of the half disc."

A knowledge of the stresses induced in timber is of very considerable importance, since these furnish a test, or at least indications, of the method and character of the treatment to which the wood has been subjected with the view of securing equality of moisture distribution. In the manufacture of aeroplanes, as Mr. Tiemann points out, temporary stresses in the timber employed should be particularly avoided. In the construction of the smaller parts, case-hardening may have little deleterious effect, but in propellers any "appreciable case-hardening is detrimental, as the internal residual stresses may cause changes to take place in the shape of the finished parts. Moreover, these stresses may change with time, which may introduce unknown stresses in the blades, or tend to shear the glue joints. Or they may even cause checking or internal cracking to take place at some future time." The problem of the detection of these internal cracks is no part of the present inquiry, but an examination of the timber by means of X-rays would often afford ample justification of these timely remarks.

THE INSTITUTE OF METALS.

THE first paper taken at the meeting in Mappin's Hall, Sheffield University, on Wednesday, September 24, was the one by Dr. W. H. Hatfield and Captain G. L. Thirkell, on

SEASON CRACKING.

This paper, which we publish in full in the present issue, was read in abstract by the first-named author, who stated that an example of season cracking having come to their notice in the case of a brass plant bowl, they carried out upon this chemical and metallurgical investigations. They also span a series of cups made from sheet brass. The paper describes the method by which the internal stresses were estimated. Different cups were annealed at varying temperatures to determine the effect of such annealing upon the removal of the stresses which had been proved to exist in the spun condition. Cups in the spun and in the variably annealed conditions were placed in mercurious nitrate and by the corrosive action of that reagent, the liability to crack was determined. The authors' conclusions were that spun brass articles may contain internal stresses approximating to the maximum stress of the material. This stress in tons per square inch tensile of the original brass bowl was in the neighbourhood of 22 tons to 25 tons per square inch in the hardest portions, and in the actual experimental spun cups stresses were attained approximating to 20 tons per square inch. The examination of the original specimen showed that corrosion had an important bearing upon the formation of the cracks, and it was, therefore, considered that the experiments established that the cause of the cracking lay in local weakness, resulting from the discontinuity of surface produced by corrosion inducing a local concentration of the stresses already existent in a spun article. It was established that the objectionable internal stresses may be removed by annealing. The paper showed that with progressively increasing annealing temperatures, the internal stresses are reduced to zero, also that it was not reasonable to look for an explanation for failure in the postulated properties of an amorphous film existing between the crystals. Views shown on the screen gave evidence that the cracks ran through the crystals, also that one crystal was smashed in two by the process of work and corrosion eating through it. The paper also detailed physical experiments carried out with rings, and the behaviour of the latter when cut. Dr. Hatfield referred to a paper by Dr. Rosenhain and Mr. Archbutt read before the Royal Society, in which they dealt with the film of amorphous material between the crystals and ascribed physical properties to that film; he differed entirely from them on that point.

Dr. Rosenhain, who opened the discussion, stated that the paper read before the Royal Society referred to by Dr. Hatfield, on "Intercrystalline Fracture of Metals under Prolonged Application of Stress," had been distributed to the public only a few weeks ago, and was not yet generally known. It might be that the authors of the paper then before

the meeting had, also, not had time yet to carefully read it. The authors (Dr. Hatfield and Captain Thirkell) had carried out experiments with rings cut from the experimental bowls, these were very pretty experiments if carried out with due accuracy to justify the solution put on them. But when cutting out a ring and dealing with this separately, it should be remembered that that ring was no longer supported by the formerly supporting neighbouring material, and the stresses on the separate ring were quite different from those in the actual cup. Further, if any error were made in the thickness measurement of the ring, that error was proportionately translated into the stress determination. The authors' Table B showed numerous variations in parallelism of the sides, and some rapid tapers. Here Dr. Rosenhain showed an aluminium alloy in the shape of a piece of sheet having different bends and where cracks were liable to occur, pointing out intercrystalline fracture although a crack in a crystal here and there might very well occur. He also showed two small cups of an aluminium alloy made in 1916, one annealed to 250 deg. C. then spun and annealed again, which, if scratched, would not break; also another similar cup annealed to 450 deg. C., spun half-way, annealed again and which cracked. Stresses did not account for the whole occurrence. A sample of lead on which no cold work whatever had been done, showed acceleration of cracking by corrosion, therefore, cold work was not essential to the occurrence. Here, Dr. Rosenhain exhibited lantern slides which distinctly showed the cracks to follow the lines of the crystals, though, as he stated previously, one of the crystals was run through by the crack. One slide showed the outlines of the crystals to be vague, and in that instance the material would not season crack. In steel, the cracks also followed the outlines of the crystals. He did not think the authors had explained away his (Dr. Rosenhain's) contention of the part played by the amorphous intercrystalline film. He also gave figures and showed a sample of a cold-worked alloy, the physical properties of which were improved by cold working, but which hardened and became brittle by annealing. That metal was largely in an amorphous condition, its actual melting point was 350 deg. C. It bent nearly double, then snapped short.

Dr. F. C. Thompson congratulated the authors upon their experiments, and particularly upon their having adopted the method put forward by Mr. Stanfield for determining the stresses due to cold work; that method was a most useful one for hollow material, and one of extreme simplicity. He agreed with a very large proportion of the statements put forward by the authors, but thought that the full effect of cold work in regard to season cracking required further investigation. There were, however, instances in which the severe stressing of material led to season cracking. In season cracking three points had to be considered, namely, the entirely structural cracks, the time factor, and the kind of work put upon the material. Dr. Rosenhain had mentioned 450 deg. C., which was a very high temperature for the heat treatment of an aluminium alloy. He (the speaker) agreed with the authors in their statement to the effect that their experience with the experimental spun cups led them to discountenance the possibility of such low temperatures as room temperatures annealing brass; at any temperatures above the atmospheric changes would take place, but the nature of the changes was very difficult to appreciate.

Captain Thirkell, in the course of a brief reply, pointed out that the differences in the thickness alluded to by Dr. Rosenhain were exceedingly slight and would not affect to any great extent the resistance per sq. in. quoted in Table B. He also showed how a ring shaped itself in being "nipped" and how it opened out to a semi-circle when cut. Dr. Hatfield, who followed, referred to Dr. Rosenhain's contention that the amorphous material was the only material which came into play. He thought it wiser to consider the properties of the crystals of which the metals are made. He laid emphasis upon the various physical properties of the crystals themselves of different metals and thought, like Dr. Thompson, that Dr. Rosenhain endeavoured to embrace in one empirical theory too many facts. The behaviour of Dr. Rosenhain's lead sample was quite different from season cracking. Here Dr. Hatfield exhibited two samples of nickel-chrome steel tested in the hot state and these showed, at 200 deg. C., 40·8 tons maximum stress, 20 per cent. elongation and 45 per cent. reduction of area; tested at 1,050 deg. C. the corresponding figures were 1·3 ton, 75 per cent., and 99·95 per cent. In showing these latter samples, Dr. Hatfield's object was to afford a further illustration of the fact that the crystals did alter in their physical properties and that the crystals were fundamental, the amorphous film being purely hypothetical.

The authors added that they would reply fully in writing to the points raised in the discussion, and on the motion of the chairman, they were accorded a cordial vote of thanks for their communication.

The Ternary Alloys of Tin-Antimony-Arsenic.

The next paper taken was the one having the above title, by Dr. J. E. Stead; it included notes by Mr. L. J. Spencer, M.A., F.G.S.

It was read in abstract by Dr. Stead, and points to the formation in the alloys dealt with of spherical shaped crystals. It was not discussed; all remarks concerning it are to be communicated in writing. We intend to publish this paper in a future issue.

The Properties of Standard or Sterling Silver, with Notes on its Manufacture.

This paper was then read in abstract. It was contributed by Mr. W. E. A. Smith and Mr. H. Turner. It stated that standard or sterling silver, which contains 92·5 per cent. of silver and is the only silver alloy of industrial importance, derives its name from the fact that, from very early times, it has been the legal standard alloy for all British silver coinage and, so-called, silver-plate. The aim of the paper was to record a number of tests made on the metal and to draw attention to important details to be observed in its manufacture. When the alloy is cast, there is a tendency for the silver to become concentrated in the middle of the ingot, but when proper precautions are taken the differences in composition in different parts of the ingot are not sufficient to interfere seriously with the application of the alloy to minting and to industrial purposes. The authors found the temperature of the metal in the crucible, when ready for casting to be about 1,200 deg. C., and that of the stream during pouring to be about 1,113 deg. C. The best temperature for annealing in works practice had been found to be 670 deg. C. for all-round work. The time varied according to the thickness of the sheet but, generally, annealing was complete in from 20 minutes to 30 minutes. The maximum Brinell hardness of standard silver was about 183. The maximum tensile strength varied from 11 tons to 14 tons per sq. in. according to the method of casting.

The discussion was opened by Mr. F. C. Robinson, who stated that the paper was a valuable addition to the literature on the subject, specially in regard to physical tests. Since the metal had to undergo rolling, stamping and other work, it had to be of the best physical quality to pass successfully through all the stages, not so much perhaps from the point of view of the user, but from that of the manufacturer, and in this respect silver differed from steel. The authors had stated that the properties of tensile strength and malleability were very important in connection with the working up of sheet metal, and the figures in regard to these were very welcome. In reference to segregation, the information given was of sufficient importance to warrant them in hoping for further data. The authors had given the results of assays of drillings taken in one instance, quoted in the paper, from eleven points in an ingot, when the difference between the highest and lowest results was 1·4 per cent.; these results confirmed his (the speaker's) own, but his differences were greater; the authors should have taken drillings at the very edge, when they would have found a greater difference. These differences in assays were influenced by the temperature of pouring, by the mould and the temperature of the mould. The cause for segregation and the character of the latter had often puzzled him; one would have expected to find the centre of the ingot poorer in silver, but the centre and also the top of the ingot were both higher in silver, and the author's explanation of a "pasty stage" in the period of cooling to explain this point was satisfactory and welcome. One of the statements of the authors to the effect that commercial fine silver is never perfectly pure should be taken in conjunction with another statement of theirs to the effect that silver to be called fine in the trade must not be under 998 fine. He would like to point out that silver is put on the market only in that state of purity. In regard to this point, he added that greater purity than this can be attained; he had obtained silver at 1,000 fine and could guarantee 999·9. With reference to oxidation, the authors had worked several specimens for one hour at 815 deg. C. under oxidising influences, no specimens showing oxidation round the crystal boundaries. On the other hand, they said that if the atmosphere in which the silver was heated was strongly oxidising, the surface of the metal would become coated with a layer of copper oxide, increasing in thickness the longer the metal was exposed in a heated condition to the oxidising influence. All would agree with the latter statement, but it was difficult to reconcile the two remarks.

Mr. F. Johnson found the paper a most valuable one, and one which would be most useful for reference purposes. The authors had plotted in two instances hardness figures against numbers of passes. In view of other papers by himself and other experimentalists, he would have plotted the hardness figures against the proportional reduction in the thickness. The authors had drawn the attention of silversmiths to the possibilities of conducting the annealing in a salt bath, such as was used successfully for annealing and tempering small steel articles, and he (the speaker) would ask them whether they had considered annealing in an atmosphere of superheated steam. The authors' micrograph, Fig. 5, showed the structure of an eutectic alloy of silver-copper, having at the left-hand top corner two grey patches; were these due to a defect in the photograph or were these actual enclosures of an oxide? Their statement to the effect that a reducing atmosphere in melting has a tendency to be absorbed by the molten metal, should be made clearer by stating the substances that are absorbed. In referring to soldering operations, the authors had suggested keeping to a dull red heat, instead of reaching what often became a white heat, but he suggested that a white heat was not reached in soldering, that being nearer the melting heat.

Dr. S. W. Smith preferred to use the term "liquation" for what the authors termed segregation. He had dealt with the point in a paper of his read two years ago. There was no doubt as to the metal being richer in the centre, and the amount of liquation was governed by the conditions in which the metal cooled. The occurrence was not confined to silver alone, but was met with in other alloys, and this fact should not be lost sight of. The authors' two diagrams showing the parts assayed, and the figures of the assays indicated that the centre and top were richer in silver, and the last parts to solidify were poorer. The metal in cooling tended to resist a change of state, and the only way the outer part had to resist was to change its composition, more copper tended to go to the outside of the ingot, hence the results found in the assays.

The authors stated that they would reply to the discussion by correspondence. On the motion of the chairman they were accorded the thanks of the meeting.

On Graphite and Oxide Inclusions in Nickel-Silver.

This paper was then taken, and was read in abstract by its author, Dr. F. C. Thompson. It stated that as was the case in cupro-nickel, the precipitation of graphite from carbonised nickel-silver occurred around the crystals. This graphitisation, which occurred on annealing the metal at temperatures above 700 deg. C., rendered the alloy extremely brittle. It occurred first at the surface, and then passed inwards.

Some Notes on the Constitution and Metallurgy of Britannia Metal.

This contribution, by Dr. F. C. Thompson and Captain F. Orme, was then taken, and was read

in abstract by the latter. The analysis of the alloy used was tin, 93·38 per cent.; antimony, 4·70 per cent.; copper 1 per cent.; lead, 0·56 per cent.; iron, 0·36 per cent.; bismuth nil. The paper described the melting and casting operations, and the subsequent treatments and tests of samples. The quenched sample was up to a point distinctly harder than either the sample as received or that reheated. The cause of hardening lies in the rate of cooling rather than depending upon the temperature from which the alloy is cooled.

Dr. R. S. Hutton, who opened the discussion, referring to the paper just named, said it was an interesting one. It dealt with "Britannia Metal," and he did not know whether the name was a satisfactory one. The metal, however, was known on the Continent as "metal anglais." The authors had worked on the cast metal only, but there was more industrial interest in the metal worked up. He (the speaker) had also dealt with the same metal, and had tried to increase its hardness; he showed a number of specimens, those which had been annealed having a pronounced ring as compared with those unannealed. A suitable heat-treatment also increased the stiffness.

Mr. W. R. Barclay, dealing with the communication on graphite in nickel-silver, said this was a most important subject, particularly for Sheffield, and also for Birmingham. There were two faults makers were, more or less, liable to come up against, and those were the presence of carbide and oxidation, and to guard against these the work had to be carried out in opposite directions. He (the speaker) was working on the same lines as the authors.

Mr. F. Johnson asked the author (Dr. Thompson) whether he thought that the carbide improved the metal *qua* carbide, or owing to a simultaneous decrease in the proportion of oxygen.

Dr. Thompson, in the course of a brief reply, said he would be glad to carry out experiments on Dr. Hutton's specimens. Messrs. Heyn and Bauer, in experiments made by them in 1911 with bearing metal, found an improvement to occur as a result of rapid cooling. In regard to Mr. Johnson's question as to how far the carbide or the oxygen intervened, he could not say, no experiments at all having been carried out dealing with this point.

The authors received the thanks of the members for their communications, and the meeting was adjourned to the following day. On the members reassembling in the Mappin Hall of Sheffield University, on Thursday, September 25, the following paper, entitled

Observations on a Typical Bearing Metal,

by Miss Hilda E. Fry and Dr. Rosenhain, was first taken. It was read in abstract by Miss Fry, and we propose to publish it in a future issue. It embodies the results of an investigation into the effects of pouring conditions on the microstructure and hardness of a white bearing metal of the composition copper 4·4 per cent., tin 86·8 per cent., and antimony 8·8 per cent. The results show that the methods of casting such an alloy influences the microstructure to a marked degree, and that by varying the temperature of pouring and the type of mould great variations in grain-size can be produced. Not only does slow cooling result in a coarse structure and rapid cooling in a fine-grained structure, but the relative temperatures of the molten metal and the mould have a pronounced influence on the uniformity of grain from side to side of the casting. The Brinell numbers for this alloy indicate that though the chill-cast ingots are generally harder than the sand-cast, there are no very great differences in hardness to correspond to the differences in casting conditions. A remarkable feature is that hammering of the ingots results in appreciable softening which is more pronounced if the cold work is followed by a light annealing treatment.

The discussion was opened by Eng.-Vice-Admiral Sir George Goodwin, who said that the authors' observations described in the paper were of great interest to engineers; they formed the commencement of a series of experiments which might throw much light upon the question of bearing metals. Years ago in the Navy there had been much trouble with the white metals, and trials had been made, among other alloys, with some having 8 per cent. of antimony, a large range of copper, and the rest made up of tin. There had been a wide difference of opinion in and out of the Service with regard to the amount of copper to be put into the bearing metal. Some were in favour of using 2 per cent. of copper, others 7 per cent., and others added 2 to 7 and divided the total by two, the quotient seeming to act very well. When the metal was made there were the bearings to fill; the bearing was placed with its axis horizontal, the metal was poured in, when at the bottom there was a chilling action, the metal in the horns cooling more slowly. When the metal was cooled it was hammered to get it as close and as sound as possible. It might be that this hammering did the metal a lot of harm. Of late years, however, the Navy had but little trouble with their bearings. He thought the failure of a bearing must be due to the breaking down of the oil film. Before the advent of the steam turbine, the pressures on the bearings were from 40 lb. to 70 lb. per sq. in., and there had been trouble with those pressures. Since the use of the turbine and with the Michell thrust-block, the bearings were redesigned for a pressure of 200 lb. per sq. in., and they worked very satisfactorily for a short time at pressures up to 500 lb. per sq. in. and 700 lb. per sq. in. If the pressure had been too high on the journals it was to be expected that it would have been too high also in the pads of the thrust block, and the fact that the latter acted satisfactorily showed that those pressures were not too high. Any recorded failures showed that they were attributable more to maltreatment of the metal than to the working pressures. The authors' paper had a certain relation to the one by Messrs. Thompson and Orme read on the previous day. He hoped the authors and all others who worked on these alloys would continue their investigations.

Mr. L. Rolfe said that the ingots made at his works of metal for bearings for marine purposes were of slightly different composition from the metal dealt with by the authors; he used copper 6·5 per cent., antimony 8·5 per cent., the remainder being tin, and the metal was poured at 500 deg. C. to 600 deg. C. in the ingot moulds. He did not find any difference in the surface of the ingot sides and bottom, the top was of course open to the air. The structure was very regular. In the re-melting, the bearing shell was heated to 300 deg. C. or 350 deg. C. in an oven, the core was heated also. When the bearing was cast, the core and shell were between 100 deg. and 150 deg., and the metal between 400 deg. and 450 deg. The chilling question did not come in, they could not see any chill on the inner surface of the bearing. But the chill would not matter since the subsequent machining out would remove it. Mr. Rolfe here exhibited lantern slides giving the general structure he obtained in cast ingots, showing the average size of the compounds, where the cuboids were 1·1 mm. in width, the cuboids in the bearing being 0·5 mm. and distributed perfectly regularly. He did not think the Brinell hardness number in this case conveyed much information. It was entirely a matter as to how the crystals behaved in service. From an examination of bearings in actual service, of both good and not so good quality, the small size of the cuboids he pointed out was about the best. He found no attempt made by the authors to correlate the microstructures with the behaviour of the bearings in actual service.

Dr. F. C. Thompson, who followed, thought perhaps the predominant feeling of the meeting was one of disappointment at the authors having followed a line which had been well explored already. He referred to the work already done by Heyn and Bauer on practically identical ground. The white metal dealt with by the authors was practically similar to that forming the subject of his (Dr. Thompson's) and Mr. Orme's paper of the preceding day, as stated by Sir George Goodwin. He (the speaker) thought the Shore scleroscope hardness test was better than the Brinell test in this particular case, as it revealed greater differences following different heat treatments. The authors had said that with light etching the ground-mass showed light and dark patches; if they looked at his and Mr. Orme's micrographs 4 and 5, specially the latter, they would find that this ground-mass had essentially the characteristics of a copper-tin eutectic. The authors had referred to an ingot cast at 300 deg. C. which they regarded as the lowest temperature at which pouring could be carried out; Heyn and Bauer had given a cooling curve of a metal practically the same and in their case the curve had a peak at 360 degs. where solidification commenced; 300 deg. was therefore rather low for casting such an alloy.

In replying very briefly to the discussion, Dr. Rosenhain said the paper served a useful purpose in that it called attention to the white metals, and there were few papers so far on the subject in the Proceedings of the Institute. The fact that work had been done elsewhere should never act as a deterrent. In regard to the points raised by Sir George Goodwin, the matter of the oil film and its maintenance was one which all engineers appreciated, the pressure and speed reactions on the oil film were far from being negligible; the oil was under a vertical pressure and also under a horizontal pull. What occurred was that the oil was drawn round under a high pressure and the temperature developed, which was high for such an alloy, tended to drag away first the softer particles of the metal, then the harder particles, when trouble would commence. The official specifications on bearing metals led the authors to look into the question of these metals for themselves. Sir George Goodwin had bearings much larger than 12 in. in diameter; Mr. Rolfe had, on the other hand, bearings of probably 2½ in., and matters in this connection were quite different. Dr. Thompson had referred to his own paper; it was not an earlier one than the authors', it was a simultaneous one, since both had been read at the same meetings. Dr. Thompson had said that the ground-mass had the characteristics of a copper-tin eutectic, probably it had, but he (the speaker) would not like to emphasise that point. He (the speaker) did not find the 360 deg. referred to by Dr. Thompson, but 306 to be the figure and the peak to be at that latter figure. With regard to the Brinell and the scleroscope tests, the time rate came in, and the deformation by pressure or shock was different. So-called hardness tests had but very little meaning in the case of these bearing metals.

On the motion of the chairman, the authors were accorded the cordial thanks of the meeting for their paper.

The Solidification of Metals from the Liquid State.

The paper having the above title, being the second report to the Beilby prize committee of the Institute of Metals, by Dr. C. H. Desch, was then read in abstract by him. It referred to the first report of 1914 and dealt with two questions which had arisen in the course of the main investigation, namely, the form of crystal grains and the conditions of cellular convection. If the forms of crystal grains were determined by surface tension, as is required by Quincke's hypothesis, they should resemble very closely the cells in a mass of foam. Foam cells, whilst variable in shape, tend to resemble the pentagonal do-decahedron. Grains of beta-brass, isolated by means of mercury, are found to be very similar to foam cells. The polygonal boundaries of crystal grains in plane sections had also been examined and compared with the theoretical sections of the polyhedra which would be produced by growth from centres under certain conditions. A comparison of the diagrams obtained led to the conclusion that surface tension had an important share in determining the form of the grain boundaries, although it did not follow that Quincke's assumption of the preliminary separation into two liquids was true. Two forces, that of surface tension and the directive force of crystalline cohesion, were opposed to one another, and their resultant determined the boundary. The second part of the paper described experiments to determine the difference of temperature between the centre and periphery of a convection cell in a liquid cooling under the conditions of Bénard's experiments. Differential thermo-couples of fine wire had been used and the results showed that the difference of temperature might amount to 6 deg. C. or even more in the cells of molten wax 18 mm. in diameter, or about 1·5 deg.

in cells of soap solution 30 mm. in diameter. Such differences were quite sufficient to account for the preferential freezing at the borders of cells which was sometimes observed.

Dr. Benedicks, who opened the discussion, said he was extremely pleased he had attended the meeting. He congratulated the Institute for the admirable activity it had displayed in such a short period of time, and also congratulated the author for his remarkable work. His was a step in the right direction for increasing our knowledge of metals. The experiments described by the author were of great value and originality, and the very first on this capital point so far as he (Dr. Benedicks) knew. A professor of Heidelberg had expressed the opinion that "alles ist Schaum"—everything is foam, and we had probably to deal with the matter on that hypothesis. He (the speaker) said that almost all bodies consisted of different phases and capillary action came into play. This had already been expressed by others and particularly by Currie. With regard to surface tension having influence upon the solidification of grains of metal, it was necessary to point out the distinction to be made between two different forms of structure in the solidification of metals. As stated by the author, crystallisation started from distinct points in the metal, and here Dr. Benedicks pointed out the starting of crystallisation on the blackboard. Starting from definite points crystallisation went on at the same speed round those points. It was easy to understand how boundaries were found in different metals. He showed the boundaries round the points and how there was produced a cellular structure round the points, also how the surface action had nothing to do in the matter. His lines were not lines of minimum surface; Quincke did not go for these boundaries. If the sample were considered under a high magnification, there occurred the well-known dendritic structure of grains which he (Dr. Benedicks) showed on his sketch. As stated by Belaieff, the structure was one "of great crystals." On the dendritic crystals, surface tension had an effect, but not on the primary. He pointed out how transformations started from the corners of the main crystal. Through greasy cell walls impurities were able to go into the cellular boundaries, but this was not a reason for saying that oily cell walls existed beforehand. In regard to the second part of the paper, on cellular convection and crystal grains, the author was inclined to think that local differences of temperature were without importance in the solidification of ordinary masses of metal. But on this matter, he (the speaker) was not so sure as the author and he believed that the influence was greater than the author may think. He showed on the blackboard a point on the wall of an ingot where the temperature was lower; crystallisation started from that point and the liquid being somewhat colder there, there was a falling down stream circulating in circles downwards as he showed on the blackboard, at the boundary of the solidification of the metal, and the gases on the metal solidifying had the best opportunity to escape at the centre. The occurrence might help the primary structure of solidification. It had been said that the columnar structure of basalt could be ascribed to that kind of action, which was perhaps true. He showed on his sketch the crystal formation round the eutectic, branches went out from the crystals, the dendrites were distinct from the crystals and there must have been a convection stream from a point he showed. On the whole, he thought one must hold the possibility of convection currents having greater influence than was at first believed.

Dr. Zay Jefferies, in the course of a few brief remarks, said the main object of the author's paper was to test Quincke's hypothesis; he had approached the subject on new lines and his work would be found most valuable. A cavity did not exist in the centre of each grain, but at the grain boundary. He instanced the example of tungsten which, when melted at all, could be retained in the molten state for only a short time. The final shape of the grains was that to be considered; the primary shape of the grain did not control the final grain size. He gave also instances of solidification of metal, the grain growth taking place when the metal was partly liquid and partly solid, some grains were columnar and in the final cast the shape of the grains was very irregular.

Dr. Bengough expressed the interest with which he had read the paper and added that Dr. Desch had dealt with the subjects in a classical manner; he had no doubt that he (Dr. Desch) would arrive at very important features. He (the speaker) had a very curious structure to put before the meeting. He showed a slide of extremely pure copper, containing only traces of silver, and this had distinct signs of crystalline structure; there were many crystal grains per cell. In another slide the structure and crystal boundaries were seen. He pointed out where there might have been an emulsion on another slide and suggested there was some pre-crystalline structure in pure copper.

Mr. Cosmo Johns stated that the author's first report and the present one together were of the greatest importance to all those who were engaged in casting metals of various sorts. He (the speaker) had observed in the course of his work that primary crystals were always shown in large masses; they started from nuclei and extended until they met. It was during the primary solidification that phenomena were passed on to the metal which characterised it all through, those phenomena could only be mitigated, and nothing more, by subsequent treatment of the metal. The larger the masses the more important the smaller impurity. The latter would ultimately reappear and they constituted factors of weakness.

Dr. Rosenhain found that the author's work would focus interest in a study which had not been sufficiently attended to before. He (the speaker) believed that surface energy played a part in moulding the form of crystals, but he hardly believed that these forces were large in pure metal. In the case of heterogeneous alloys he thought larger surface forces may come in. He called attention to Dr. Stead's spherical crystals mentioned at the meeting of the preceding day. The remarks made by Dr. Benedicks were very interesting and suggestive. The primary structure was not stable, and in saying that he had in mind iron and steel. Lead underwent re-crystallisation, when strained, at a very rapid rate. If lead were strained, no annealing would re-arrange the crystals; the same could be said of other metals if pure enough and not subject to allotropic transformation. Gold was practically pure and there was no separation of impurities at the boundaries. The idea of separation of impurities at the boundaries, he thought, was overdone. Dr. Benedicks had referred to a dendritic structure in the eutectic, but the eutectic was literally unmixed crystals.

Dr. Desch, in the course of a brief reply, said Dr. Rosenhain had stated that surface tension was small in pure metals, but he (the speaker) would reply that a real surface tension existed between the liquid and solid phases, acting up to the last moment. Dr. Bengough's copper was not pure, it contained a little silver and that would have an effect in the action Dr. Bengough had pointed out.

On the motion of the chairman the author was accorded the cordial thanks of the meeting for his valuable contribution to the proceedings of the Institute. The chairman read, also, a letter from Dr. Beilby appreciating Dr. Desch's work and saying he would gladly place further funds at Dr. Desch's disposal to enable him to carry it still further.

Moulding Sands for Non-Ferrous Foundry Work.

The next paper taken was the one having the above title. It was read in abstract by the author, Dr. P. G. H. Boswell, F.G.S., and as we commenced its publication in full in our last number (see page 418 *ante*) and complete it in the present issue, it is unnecessary that we should deal with it further here.

The discussion was opened by Mr. Cosmo Johns, who expressed the opinion that all the knowledge in regard to foundry practice and particularly in the matter of sands was locked up in the minds of the craftsmen; very little literary work of a really useful kind existed on the subject, but mostly generalisations. The author had asked that all knowledge in the matter of sands should be put on record, and if that were done very valuable results would accrue. His information of the actions between the metal and the sand were very interesting; his reference to the distribution of the iron oxide, or clay bond was only one of the many points the paper dealt with, and which were as important in their way as the other points dealt with in the paper by Dr. Desch. There was a necessity for more careful, complete and sympathetic co-operation between the working men, who were really artists in their trade, and for an exchange of knowledge on the subject.

Professor Turner pointed out the causes for the development of large centres such as Sheffield and Birmingham. At first the power available in streams was utilised, then fuel supplies were found on the sites, also sands and fireclay, which latter were frequently of more importance than finding on the sites supplies of metal. For example, in this country we had no copper, we imported it, but we had other material which would be more expensive to move. Sand which adhered to the castings was not wanted; the question why some adhered more than others depended upon the quality of the sand and also on the kind of metal. The surface tension of the metal as compared with that of the mould came into play. Another point had reference to the viscosity of the metal, and the viscosity of non-ferrous metals was generally very low, only a small multiple of that of water, 4, 5 or 6. He did not know the viscosity of steel when pouring, but that would show why different sands were required for steel. The author had stated that the foundry technique of the United States was less advanced than that of this country. As to this, he (the speaker) could not make a pronouncement, but he would have thought from his observations that foundry work in America was at least as advanced as here. Numerous researches had been carried out in the United States on the texture of moulding sands and on their mixtures, and Dr. Turner felt surprised at the author's remark as to this point.

In the course of his reply, Professor Boswell stated that scientific investigation during the war had borne more upon steel and iron than upon non-ferrous metals. More was known concerning the behaviour of steel in moulds than concerning that of non-ferrous metals. With steel, a scoring action in the mould took place, the steel scored off the surface film on the mould, which gave strength to the mould, and had access to the sand grains underneath. In the remark referred to by Professor Turner, he (the author) was thinking of the skill of the foundrymen; in this country the art passed from father to son; moreover, the president of the American Foundrymen's Association and other authorities in the States had told him that we in this country had a deal to teach America in the matter of foundry skill.

The chairman stated that the paper in question was one of the most valuable presented to the meeting, and that no one in this country had done more work than the author in regard to the important subject of moulding sands; on his motion, the author was heartily thanked for his contribution.

The Early History of Electro-Silver Plating.

This paper, by Mr. R. E. Leader, B.A., which was next taken, was read in abstract by Mr. Bradbury. After a brief historical review, the author referred to the finding by John Wright, a Birmingham surgeon, that cyanide of potassium solved the problem of silver deposition. The date was September, 1840. Then followed information on the development of electro-silver plating, all the well-known firms and their activities in the industry being mentioned.

The discussion was opened by Dr. Hutton, who, referring to the author's statement to the effect that nickel-silver was for a long time called "German silver" although British and Scandinavian chemists seem to have played a great part in its rediscovery, said he had looked through history in regard to the point and had found that nickel-silver originated in Scotland. In Germany, a prize was offered afterwards for reproducing it in that country. There was no doubt that Germany had followed our lead.

Mr. F. Mason found the paper so very complete that there was very little to add by way of comment. It had involved a vast amount of research, the reading through of very numerous books and other

literature on the subject and the verifying of very many dates. The question as to who was the inventor of electroplating remained, he thought, a vexed problem. Electroplating was carried out before 1840, but then the deposits were thin and unsatisfactory. It was only since the advent of potassium cyanide in connection with electroplating that this was made a success. Who introduced the use of potassium cyanide? The paper referred to a process devised by Barratt, assigned to the Elkingtons and covered by letters patent applied for on March 25, 1840, for improvements in coating, covering or plating certain metals. Did that patent have reference to the use of potassium cyanide? John Wright, the paper also said, only came in line six months later; the paper adding that "the same principle was deemed to underlie both his methods and the Elkington's," it might naturally follow that the patent of March 25, 1840, referred to the use of potassium cyanide. The honour would therefore be a joint one.

Professor Turner welcomed the paper since it fairly and frankly represented the position of electroplating in the early days, and the great discoveries made in Sheffield and Birmingham. The latter city was grateful to Sheffield for putting the subject in so fair and concrete a form.

On the motion of the chairman, the author was accorded the thanks of the meeting for his contribution. Time not permitting the meeting to deal with the paper by Dr. Zay Jefferies, Cleveland, Ohio, on "The Micro-Mechanism of the Ageing of Duralumin," it was taken as read, and will be discussed by correspondence.

A vote of thanks to the Reception Committee and to Sheffield University, and the announcement that the next spring meeting would take place on March 11 and 12, terminated the proceedings.

PORTABLE MILITARY BRIDGES.*

By Professor C. E. Inglis (Major, R.E., O.B.E.).

(*Concluded from page* 409.)

Rapid bridges for motor lorries were without doubt by that time urgently required, and the great development and extreme importance of this class of traffic appeared amply to justify a special design. A design was accordingly prepared and submitted overseas.

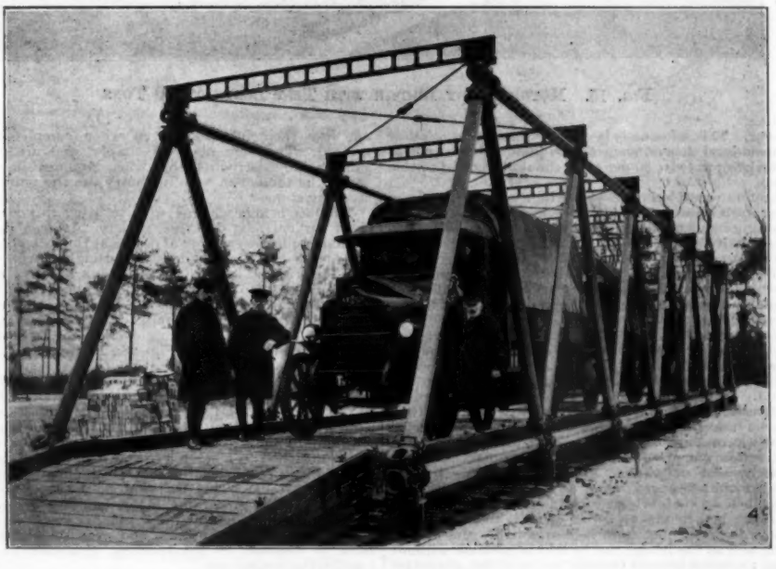


Fig. 9. Motor Lorry Bridge.

Taking into account the fact that the previous types were then only partially digested, it is not to be wondered at that the authorities showed some hesitation in embarking on a new venture. The matter, however, was settled by the firm of Messrs. Kryn and Lahy, who were the manufacturers of all but the first two experimental bridges. With praiseworthy enterprise this firm offered to build a sample of this new design free of cost and send it for approval overseas.

Such an offer could hardly be refused, and this courageous action on the part of Messrs. Kryn and Lahy was speedily rewarded by the receipt of substantial orders from Mesopotamia and France before even the first sample of this new type had been completed. This motor lorry bridge is shown in Fig. 9.

It will be seen at once that the design differs in one important respect from its predecessors in that, in order to obtain a sufficiently commodious traffic gauge, the pyramid form of construction is abandoned.

In the design of the main joints and in the method of launching the system remained unchanged.

This type of bridge was used extensively during the last rapid advance stage of the war, and before proceeding to describe a yet more substantial structure which was evolved for the use of the Tank Corps, a few of the more interesting and important points in connection with the design of this particular bridge will be indicated.

I will accordingly ask you in the first instance to consider the main joint, which is represented on the three Figs. 10, 11 and 12. This type of joint was common to all these tubular bridges both light and heavy.

A is the junction-box made of cast steel, shown in elevation in Fig. 10 and in section in Fig. 12.

B is a steel tongue permanently screwed into the thickened end of a tube member.

C is a collar or nut which turns freely on a fine thread (11 threads to the inch) cut on the outside of the tube.

To make the connection the nut is run back on its screw two or three turns, and the tongue inserted into the junction-box. The pin D is then passed through the slot in the tongue and through the two corresponding slots in the sides of the junction-box.

The semi-circular ends of the slots are machined to fit the pin; in other positions the clearance between the pin and the sides of the slots is at least ⅛ in., consequently there is no difficulty in inserting the pin provided that the nut is slacked back sufficiently. At this stage the connection is in the nature of a pin joint with ⅛ in. or so backlash.

This backlash is then taken up by screwing the nut into contact with the machined boss at the end of the junction-box. Continuing to screw, the tongue tends to draw out of the junction-box until further movement is resisted by the pin bedding itself firmly between the three bearing areas at the ends of the slots. The connection thus tightened up is in effect a stiffened pin joint, and the ends of the tubes are rigidly constrained in direction; a circumstance which adds materially to their power of resistance when acting as struts. In the case of compression members the load is all transmitted through the nut, and in the case of tension members the pull is resisted by the pin.

This type of joint is peculiarly fool-proof and dirt proof. The screw thread outside the tube is always protected by the nut and the positions of the bearing surfaces inside the slots renders them almost perfectly immune from accidental damage.

Perhaps the most difficult problem encountered in the whole design of the bridge was the determination of a thoroughly satisfactory method of connecting the tube ends permanently into the tubes.

The ideal aimed at was to obtain an attachment possessing an efficiency of over 100 per cent., or in other words an attachment which would break the tube rather than let go.

In the very first light bridge in which the tubes were of comparatively thin gauge a fairly satisfactory connection was made by rolling the tube into shallow corrugated grooves turned in the cylindrical portion of the tube ends in the manner indicated in Fig. 13. For thicker tubes it was found that in forcing the tube well down into the grooves the walls of the tube in the region of the grooves became appreciably reduced in thickness and the strength of the tube suffered in consequence. The oxy-acetylene welded connection illustrated in Fig. 14 was then tried.

Samples of this attachment under test gave excellent results, and this type of connection was adopted in the construction of No. 2 experimental light type bridge.

This connection was never quite up to the full strength of the tube, but it did not fall far short of it and was quite capable of stressing the tubes well beyond their elastic limit. However, after a brief reign this method of attachment was abandoned owing to the human element making itself apparent as soon as production on a large scale was called for.

If carried out by really skilled and experienced workmen the results were satisfactory, but there was no room for faulty work, and unfortunately it is quite impossible to detect a faulty weld by a mere superficial examination.

Each attachment had to be tested separately under tension, and the number of failures under test was so serious that this type of connection was hastily abandoned.

The method of attachment which was finally and satisfactorily adopted is shown in Fig. 12.

The tube end in this design is screwed into the tube which is thickened at its extremities to compensate fully for the loss of section due to the cutting of the inner and outer screw threads. The attachments at the opposite ends of the tubes are screwed right and left-handed respectively, and in this way the distance between the pin centres of the two end tongues can be adjusted to any desired degree of accuracy.

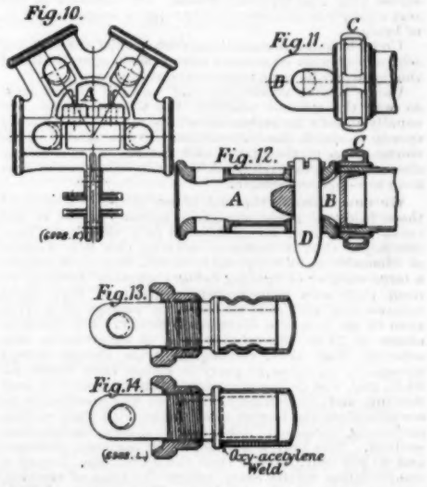
The nut enclosing the end of the tube effectively eliminates all possibility of the attachment escaping by bursting the end of the tube.

This type of connection gave entire satisfaction and, although the practice was continued of testing all tubes in their finished state nearly up to their elastic limit, this test was continued more with the object of eliminating the faint possibility of a burnt tube than in the expectation of a faulty attachment which never from the first gave any cause for anxiety.

The tubes were of the lap-welded variety made by Messrs. Stewarts and Lloyds, at Coatbridge. This firm went to exceptional trouble to meet the somewhat exacting requirements laid down, and after the initial difficulties had been overcome they produced a steady supply of excellent tubes, with most gratifying and praiseworthy punctuality.

In order to ensure a good weld which would stand up under the drastic process of staving the ends, the steel employed was of a soft mild description having an ultimate tensile stress of about 28 tons per square inch and an elastic limit which was usually about 14 tons per square inch, though not more than 12 tons was guaranteed by the makers.

The main joint is a steel casting somewhat complicated by the two projecting plates by which the joint is permanently attached to the web of the transom, which was a 14-in. by 6-in. R.S.J. Although intricate, this casting



presented no difficulty to the makers, Messrs. Kryn and Lahy. They excited the admiration of all who understood the difficulty of producing high-class steel castings, and the number of wasters the firm had to reject was quite negligible.

They were cast from steel made in an electric furnace, and the nature of the material so produced in the matter of ductility yield-point and ultimate strength closely resembled a high-class mild steel.

This indeed was so much the case that the tongues screwed into the ends of the tubes were also steel castings, and this somewhat unconventional practice was justified by the fact that out of the many thousand tube ends cast from electric steel there was no single case of failure under test. In contrast to this the tube ends of the light bridge were machined out of the solid, and in this case several failures occurred under test owing to undetected flaws occasioned by piping in the solid rounds out of which the tube ends were machined. Profiting from previous experience this rectangular bridge was made considerably stronger than the needs of the moment

* Paper read before Section G of the British Association, at Bournemouth, September 10, 1919.

dictated, and it was designed to carry a dead load of 84 tons distributed over an 84-ft. span. Fig. 15 shows the bridge carrying a test load of 100 tons of pig-iron.

The central deflection produced in this case was 1¼ in., which was entirely eliminated on removing the load and proved thereby a complete absence of over-strain.

Under the load of 84 tons the maximum tube stress was limited to 7½ tons, or about half the elastic limit of the tubes, and the external diameter of the tubes was arranged so that the compression tubes were not loaded up to more than one-third of their theoretical buckling load.

These two conditions definitely prescribed the outside diameter and the thickness of the tube, which for the horizontal members were 5⅛ in. and ⅜ in. respectively, and for the diagonal tubes 5⅛ in. and ¼ in. Fig. 16, on Plate XXII, shows a bay of the bridge in skeleton. The length of each bay is 12 ft. The width and height measured between the centre lines of the tubes are also 12 ft. A bay in skeleton weighs about 1¾ tons, and complete with decking a 96-ft. span, or eight bays, weighs 25½ tons, and this figure compares very favourably with the weight of military bridges of the girder type having approximately the same carrying capacity.

Fig. 17, Plate XXII, illustrates the nature of the decking. The road bearers, seven in number, are 8-in. by 4-in. steel joists, with their ends resting freely on the transoms, which are provided with cleats to preserve the correct spacing of the road bearers. The two outside joists are fitted with cast steel buttons pitched 9 in. apart centre to centre, and into the intervening spaces the 8-in. by 4-in. pitch pine deck planks are transversely laid.

This planking is held down by kerbs and hook bolts, and the decking is completed by the addition of side screens, as shown in Fig. 18, Plate XXII, which illustrates a bay completely decked. The traffic gauge is a rectangle, 12 ft. 6 in. high by 11 ft. 6 in. wide, and the width between the kerbs is 9 ft. 4 in.

To effect the erection of the upper tubes, transverse stiffeners and bracing, a movable staging of step ladders and horizontal platforms extending over a length of two bays, is provided.

As in the case of its predecessors, the bridge was constructed on a two-wheeled trolley. This is shown in Fig. 19, Plate XXII. A noticeable feature in its design are four lifting screws by which the bridge is suspended from the trolley.

When the bridge has been swung across the gap it is readily lowered down on to its abutments by means of these screws and the trolley can then without difficulty be detached and rolled out of the way.

These lowering screws are doubly articulated at each end, which gives them perfect freedom to take any oblique direction arising from a tilt either of the trolley or the bridge.

The wheels are substantial steel castings, and their treads are cambered to facilitate the process of swinging.

It is essential in most cases to provide a rigid platform for the trolley and a double layer of the deck planks serves very well for this purpose. On a surface of this sort a couple of men can readily rotate a length of 180 ft. of bridge.

Under favourable conditions, such as exist at a bridging school, and with 80 trained men, a 96-ft. span bridge of this type can be completed in about 4 hours.

Under service conditions, and working in the dark, as was the general practice, the time occupied was usually about 8 hours, but this at any rate was sufficiently speedy to enable the construction to be completed in the course of a single night, and thereby escape enemy observation, which rendered bridge building in the day-time well-nigh impossible.

We now come to the last phase in the evolution of these bridges. After the great military value of the tanks had become an established fact, the Tank Corps recognised that in order to develop this new weapon of offence to its fullest possible extent, they must possess a large number of fighting bridges specially designed to meet their own requirements, capable of very rapid construction, and able to force the passage of a river even in the face of a determined enemy. For spans in excess of 25 ft. the tubular form of construction was selected. The 12-ft. rectangular type, though strong enough in its tubes to carry a 40-ton tank across an 84-ft. gap, was deficient in strength in its transoms and decking, and, furthermore, its width was insufficient to accommodate the largest male tanks with their widely projecting sponsons. Accordingly a new design was evolved. This bridge was about 50 per cent. stronger and 50 per cent. heavier than the 12-ft. type, but as a compensation to the extra weight the time of erection was reduced by at least a half. Fig. 20, Plate XXII, illustrates this enlarged bridge.

The bays are 15 ft. long and 15 ft. wide. The horizontal tubes are identical and interchangeable with the diagonal tubes, so that in side elevation the panels are approximately equilateral triangles having a height of 13 ft. This obvious simplification was not permissible in the case of the 12-ft. type since the height of a 12-ft. equilateral triangle did not give the headroom necessary for motor lorries. In most other respects this new bridge was merely an enlarged edition of the 12-ft. design.

The tubes have an external diameter of 6⅝ in., with a thickness of ⅜ in., and each tube complete with its end attachments weighs 4 cwt.

The narrow track of the tanks concentrates the load on the transoms to such an extent that nothing less than an 18-in. by 7-in. steel joist would suffice. The decking is supported on four 12-in. by 6-in. steel joists, and the deck planks are 10-in. by 5-in. pitch pine. Light footways on either side of the 10-ft. main roadway are an additional feature of this bridge.

The weight of a bay complete with its decking is 6 tons, of which 3 tons is due to the road bearers and deck planking. The bridge was primarily designed to take a 40-ton tank over a clear gap of 90 ft., but the span can be increased to 105 ft. without incurring serious stresses. In this connection it should be noted that the progression of a tank is so smooth that practically no allowance for impact need be made, whereas in the case of motor lorry traffic an impact factor of 2 was used in stress calculations. The reduction in time of erection was brought about by the utilisation of light tubular derricks in place of the comparatively clumsy timber staging employed previously in the process of construction.

The attachment of the tubes to the transverse stiffener was done at ground level, and a unit consisting of this stiffener with four tubes attached was hoisted up in one piece by the derricks, and only two men were required up aloft to couple this unit up to the existing part of the structure. Fig. 21, Plate XXII, shows the derrick in position performing the operation just described.

By this simple device the time occupied in the erection of a bay was reduced by one-half, and, including the shifting of the derricks, it has been found possible for erection to proceed at a rate of a bay in 10 minutes. Assuming that this rate of progress is maintained, two detachments working simultaneously at the two ends of the bridge will construct 12 bays or 180 ft. of bridge in an hour. This, of course, is a "star turn," and to allow for accidental delays, such as the jambing of a pulley-block chain, at least 50 per cent. should be added to this time.

The final completion of the bridge after it has been swung into position is also much facilitated by the adoption of an articulated, tail, which is shown diagrammatically in Figs. 22 and 23, Plate XXIII.

In the case of the previous 12-ft. type time was wasted in dismantling the tail of the bridge which generally projected into the air in a manner which made it difficult to manipulate and rendered it quite useless as a bridge approach.

In this case the tail is articulated at the trolley, and, after the counterweight has been removed, two top tubes are taken out and the tail is lowered by a worm wheel crab and tackle until its outer end rests on the ground. In most situations it then acts as a convenient bridge approach, and at least an hour of valuable time is saved thereby. The standard type of two-wheeled trolley was retained for general service, but an alternative construction was provided, which moves upon caterpillar tracks instead of wheels. By means of this trolley, provided that the ground is not too broken, a considerable length of bridge fully decked and ready for action can be brought up across country to its intended site. A tank pushing from behind supplies the motive power, and as the bridge can be laid in position without a man exposing himself outside the tank the attributes of a real fighting bridge are well realised by this construction. The heavy weight which has to be transported, however, limits the span which can be effectively dealt with in this manner to about 60 ft. Built and launched in the ordinary way, 105 ft. marks the limit of clear span which can be used with safety for the transportation of 40-ton tanks. The tank advance, of course, had to contemplate the crossing of rivers of far greater width, and for this purpose a combined tubular and pontoon bridge was designed. The ordinary form of pontoon bridge consisting of a series of short discontinuous spans was out of the question, since the great weight of the tank would have necessitated pontoons of such large dimensions that they would have completely blocked the waterway and their transport across country would likewise have presented an almost insuperable difficulty.

The design adopted is shown in Fig. 24, Plate XXIII, which illustrates the arrangement for a 240 ft. bridge. The middle portion of 120 ft. has a pontoon under each transom and is, in effect, a boat 120 ft. long, with such ample fore and aft rigidity that a tank coming on at one end merely alters the fore and aft trim of this rigid structure, and does not call upon any one pontoon to carry the whole concentrated load of the tank. Clear approach spans of 60 ft. are provided at each end, and the articulated joints referred to previously come in most conveniently for connecting these approaches to the floating portion. If articulated joints are introduced every 180 ft. or so this type of stiffened pontoon bridge admits of indefinite extension, and the construction proceeds as rapidly on water as on land, pontoons with transoms on board being floated up in turn to the head of the bridge and linked up there by means of the tubular construction. An actual example of this bridge is illustrated by Figs. 25 and 26, and in Fig. 27 a tank ferry, consisting of three pontoons and four bays of bridge, is shown in operation. The pontoons are 40 ft. long, 9 ft. wide, and 3 ft. deep. They weigh about 4 tons and require a further load of 27 tons to completely submerge them. They are divided into six watertight compartments, and, being decked over entirely, they do not lose their buoyancy even when completely submerged. They are made of timber, and are of such substantial construction that when grounded in shallow water the tanks can with impunity use the pontoons as stepping stones.

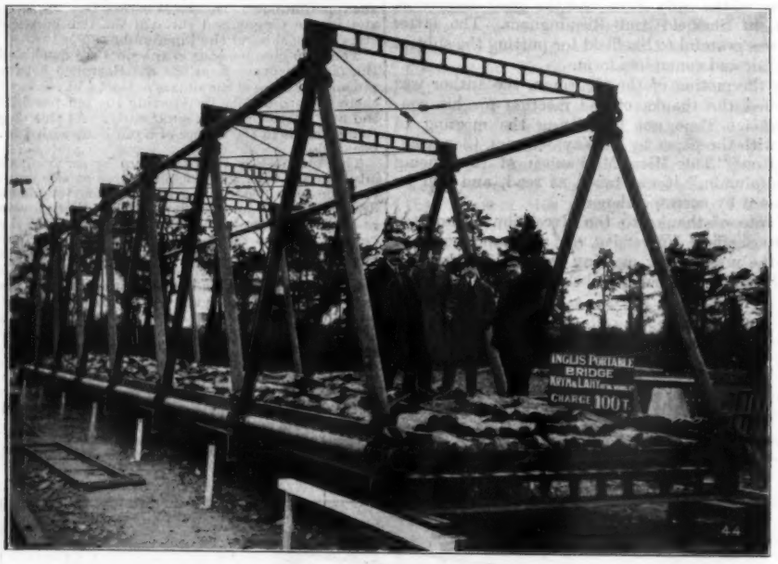


Fig. 15. Motor Lorry Bridge with Test Load of 100 Tons.

The last bridge which I wish to bring to your notice is of an entirely different variety. It was designed primarily for the crossing of canals at the lock entrances, where the clear width does not usually exceed 20 ft. The ideal aimed at was to get a tank to carry a 25-ft. span bridge so to speak in its mouth, lay it in position, and then climb across its back without a man having to expose himself outside the tank. In this way a means is achieved of forcing a crossing even in the face of close-range machine-gun fire. Fig. 28, Plate XXIII, shows the bridge in its carrying position.

The main members are 18 in. by 7 in. steel joists reinforced by top and bottom flange plates. The heel of the bridge, which is forked, rests on a strong cross-bar hinged to the tank by two triangular side frames. The remaining weight of the bridge is supported by wire rope slings attached to a steel derrick which can be raised or lowered by a tackle leading to a winch operated by hand inside the tank. This carrying position, although it looks somewhat precarious, is not found to be so. The weight of the bridge, about 3 tons, is small compared with the weight of the tank, and even thus loaded the tank is capable of surmounting obstacles of quite formidable dimensions.

On reaching the gap the derrick is lowered until the head of the bridge takes the ground on the opposite bank. The supporting slings then being relieved of tension automatically let go, and a further slackening of the tackle lowers the heel of the bridge on to the ground. Fig. 29 shows the completion of this stage. Backing away slightly, the tank detaches itself from the forked end of the bridge, and it is then free to proceed across in the manner shown on Fig. 30. Guided by strong channel irons the tank crosses upon the flanges of the girders without any intervening timber decking, which can be added subsequently and in safety after the tank advance has effectively dissipated the enemy opposition.

The design of the three types of tank bridges was put in hand in June, 1918, and it speaks well for the energy of

the manufacturers concerned that the first samples were ready for test in September. By October a steady flow of tubular bridges was coming forward and the training of special Royal Engineer Bridging Battalions had commenced at Christchurch. In consequence of the armistice none of these tank bridges saw active military service. With an establishment reduced in numbers but not in enthusiasm training and experimental work in connection with these bridges has continued, and the results of these experiments point definitely to the conclusion that in the future tanks are likely to play a prominent part in the transportation and construction of heavy military bridges.

STANDARDISATION OF SPINDLE NOSES FOR MILLING MACHINES.

TO THE EDITOR OF ENGINEERING.

SIR,—The activities of the British Engineering Standards Association with regard to the standardisation of milling cutters and small tools, will be of great benefit both to users and makers, and it is anticipated that the new standards when finally decided upon, will be widely adopted. It has not hitherto been found possible to adopt the standardisation of spindle noses of milling machines, mainly on account of the fact that there are so many machines of American manufacture in use in this country, and it is hardly to be hoped that the British Engineering Standards Association will be successful in persuading American and British manufacturers to agree to one standard for both countries. It appears, therefore, that the only course which is practicable in this country is the adoption of a standard spindle nose for British milling machines.

The design of spindle noses has changed considerably in recent years as a result of the heavier duty which has latterly been performed by milling machines, which has shown up the weaknesses of spindle noses as formerly and even now, largely made. It is generally agreed that some form of clutch drive is necessary on a spindle nose for heavy milling, and experience has proved that the clutch should be of the closed and box type with a view to avoiding distortion in use. It has also been found necessary for heavy work to harden the clutch with the same object, viz., to prevent distortion.

Screwed spindle noses have been found to be faulty for heavy work, as even when made with multiple threads, it frequently becomes impossible to remove cutters which are screwed upon them, and the tendency has therefore been on new designs to adopt either parallel or taper fits, holding the cutter back by a draw bolt through the spindle, the torsion being taken by the clutch drive.

The taper nose has advantages over the parallel nose, in that the cutters are more easily applied and removed, and more easily kept true. As makers of heavy milling machines these considerations were borne in upon us as a result of troubles which occurred with the earlier types of noses, and we believe it might be of benefit to the engineering trade generally to publish particulars of the noses which we have finally adopted, and which have been proved by considerable use during the last nine years, to be satisfactory and to be free from any practical objection.

The illustration shows the four standard noses which we have adopted, the external taper being made to a uniform angle of 7½ deg. with the axis, or, in other words, an included angle of 15 deg.

Brown and Sharpe tapers have been adopted for the arbours, as these are in almost universal use; the clutch drives are milled out from the solid as indicated. The ends of the spindle noses are hardened so that the hardening applies both to the external taper and the clutch, and both internal and external tapers are finished by grinding. There are no keys or other parts in this spindle nose which can come loose, and the design enables face cutters to be used very close up to the bearing of the spindle.

We suggest that the particulars which are now offered for publication for the first time may be of assistance to other designers of milling machines, and may lead to the adoption of a satisfactory British standard for spindle noses.

Yours faithfully,
(FOR ALFRED HERBERT, LIMITED),
P. V. VERNON, Director.

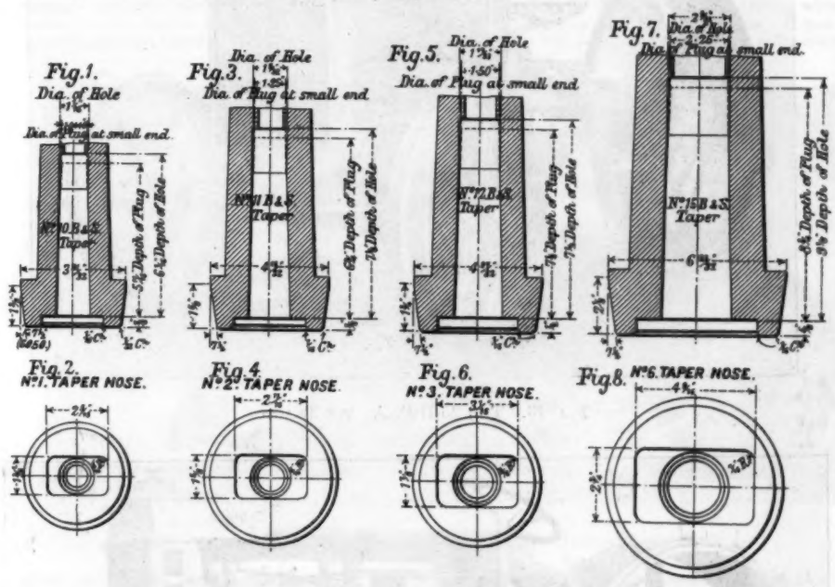
September 27, 1919.

THE MURDOCH MODEL IN THE WATT COLLECTION.

TO THE EDITOR OF ENGINEERING.

SIR,—In view of the probability of the above model being included in the new Watt collection at Birmingham with a legend attached to it intimating it was made in 1784, I would ask those of your readers who have made a special study of the early history of the locomotive to give some consideration to the following facts.

1. In Tredgold's book on the steam engine it is stated that William Murdoch invented the long D slide valve which admits on its internal edges and has an exhaust thoroughfare formed through it longitudinally. The date is given as 1799.



2. The small piston slide valve of the Murdoch model admits on its internal edges, has an exhaust thoroughfare formed through it longitudinally, and is as long as the cylinder it serves.

3. William Murdoch resided in the same district of Cornwall and for many years in the same town as Richard Trevithick, the great apostle of high-pressure steam and the builder of the first locomotive that ever ran on rails.

4. Richard Trevithick built his first locomotive to run on the public highway in 1801, and first ran it on Christmas Eve of that year.

Out of these facts two questions arise, viz.:—

1. If such an important invention as that of the internal admission piston valve with exhaust thoroughfare was produced in 1784, why was it not immediately patented and used instead of being delayed to 1799?

2. Is it not more likely that Murdoch's model was made some time in the year 1802, after the public trials of the Trevithick locomotive?

It is well known that James Watt was an inveterate opponent of the use of high-pressure steam, and that every means possible were used by Boulton and Watt to prevent the introduction of high-pressure steam engines. It is not so certain that Murdoch was opposed to high pressure, and it has never been made clear that Murdoch ever claimed to have made the model in 1784. That claim only originated from the firm of Boulton and Watt in 1850, many years after Watt, Murdoch and Trevithick had passed away.

Some time in 1894 you published an illustration of the Blenkinsop locomotive model belonging to Mr. H. C. Embleton, of Leeds. Tredgold on the "Steam Engine" states that the short box slide valve admitting on its external edges and exhausting through its box cavity (the slide valve now universally used) was invented by Mathew Murray in 1801. The firm of Fenton, Murray and Jackson, of Leeds, built the Blenkinsop locomotive of 1811, but, strange to say, the Murray slide valve was not used. Instead, the cylinders had four-way cocks (the invention of the German engineer, Leopold, in 1720) fitted exactly as Trevithick fitted them to all his locomotives and other high-pressure steam engines. It is quite well known that Trevithick either sent to or had constructed in Newcastle a locomotive for Mr. Blackett, of Wylam, which was a duplicate of the Merthyr Tydvil engine of 1803. Also Hedley, the engineer for Mr. Blackett, tried to obtain the assistance of Trevithick in the equipment of the Wylam Railway at the time the Trevithick locomotive of 1808 was running in London. Is it not probable that Trevithick was also consulted or concerned in the construction of the Blenkinsop engine? Were the cylinders of that engine designed or made by Trevithick or merely copied from his designs?

Another point on which the present writer feels rather grieved is the want of recognition of Carmichael, of Dundee, when engines, and especially American engines fitted with his reversing valve gear, have been discussed. A great many of the early Baldwin engines were fitted with that gear. In fact, you illustrated the "Pioneer" built by Baldwin in your pages in 1894, in connection with locomotives at the Columbian Exposition of 1893, (see vol. LVIII, page 574), without a suggestion that the gear was a British invention. In view of the further probability of there being a public celebration of the centenary of the opening of the first public railway in Great Britain is it not desirable that as many of the facts as possible relating to the early history of the locomotive should be carefully collected and certified, and also embodied in some authoritative publication?

Yours truly,
JAMES DUNLOP.

100, Bellfield-street, Dennistoun, Glasgow,
September 24, 1919.

"THE BUILDING OF AIRSHIPS."

TO THE EDITOR OF ENGINEERING.

SIR,—The arguments against airship building advanced by Mr. Llewelyn Davies in your issue of September 26 do not sound to me very convincing. Actually the British Government is apparently still very keen on huge dirigibles, as, to quote the words of General Seely "they are of national importance." As your correspondent "Winco" rightly points out that the reduction in the airship programme is no proof against the utility of airships. It merely implies in this case that progress in this country is temporarily stopped until we can get our house in order, inevitable after a war of the magnitude we have just passed. That Great Britain will again resume building airships at some future date is certain.

Mr. Davies' remarks on the subject of the commercial value of airships needs also some revision. What better mode of transport can there be than the airship for the carrying of urgent mails and passengers in a hurry. Let us have the tramp steamer to carry our general cargo by all means. Time is not of the greatest moment when it comes to minerals or merchandise if transportation is properly organised.

The tradition that Britain waits for other countries to develop their ideas before launching out in her own is probably true, but it does not reflect credit upon us as the first nation of the world.

In conclusion, Mr. Davies is probably unaware that other countries will possibly build airships, and for that reason alone Great Britain must build likewise.

Yours faithfully,
S. H. PHILLIPS.

Aircraft Works, Barlow, near Selby,
September 29, 1919.

UNIVERSITY MATHEMATICS FOR ENGINEERS.

TO THE EDITOR OF ENGINEERING.

SIR,—The metaphor of dry bones and flesh is overworked. It is at least fresher to represent the theory of functions as the main triangulation in the survey of a mathematical domain, which gives a sense of view and direction such as can never be given by the methods of pure geometry. To press the new metaphor a little, text books on geometrical curves are guides to local rambles among the beauties of pure geometry, and the study of the hyperbolic sine and cosine as functions of a hyperbolic sector is a sort of geometry-lover's lane, and a very pretty one! As for illustrations, these are obviously supplied by the physical problems which alone the engineer has time to study.

I am, &c.,
A. R. L.

London, September 24, 1919.

PERSONAL.—Messrs. Babcock and Wilcox, Limited, advise us that on and after Monday, September 29, 1919, the new address of their Manchester local office will be: Victory Buildings, 230, Deansgate, Manchester. Telephone number, City 3112. Telegraphic address, "Babcock, Manchester."—Captain A. H. Law has resigned the position of managing director of Messrs. C. A. Parsons and Co., Limited.

THE RÖNTGEN SOCIETY.—The following are the names of the newly-elected officers and Council of the Röntgen Society for the ensuing year: President: Sidney Russ, D.Sc. (1919). Past-Presidents for last three years, Major C. Thurstan Holland (1916–17); Major G. W. C. Kaye, M.A., D.Sc. (1917–18); G. B. Batten, N.D., C.E. (1918–19). Vice-Presidents: J. Hall Edwards, M.R.C.S. (1914); Professor A. W. Porter, D.Sc., F.R.S. (1914); Professor J. W. Nicholson, N.A., D.Sc., F.R.S. (1919). Hon. Secretaries: Robert Knox, M.D. (1911); R. W. A. Salmond, M.D. (1919). Hon. Treasurer: Geoffrey Pearce (1915). Hon. Editor: Major G. W. C. Kaye, M.A., D.Sc. (1919). Council: W. E. Schall, B.Sc. (1914); G. H. Rodman, M.D. (1915); C. Howard Read (1916); C. R. C. Lyster, M.R.C.S. (1916); J. Metcalfe, M.D. (1917); K. P. Cumberbatch, M.A., K.B. (1916); A. E. Barclay, M.A., M.D. (1919); F. J. Harlow, B.Sc. (1919); W. Nakower, M.A., D.Sc. (1919); E. A. Owen, D.Sc., B.A. (1919); J. Russell Reynolds, M.B., B.Sc. (1919); R. S. Wright, M.I.E.E. (1919).

THE AGRICULTURAL TRACTOR TRIALS.

In connection with the ploughing trials of agricultural tractors which were organised by the Society of Motor Manufacturers and Traders and were held at South Carlton, near Lincoln, last week, we publish on pages 444 and 445 a complete tabular statement giving particulars of the various tractors which entered or competed. The table is self-explanatory and does not call for any comment here. We may, however, refer to the detailed notes below which should be read in conjunction with the table. They give various additional particulars of some of the tractors, or observations on their performance. Additional information is also given by the illustrations which we publish on Plates XXIV and XXV and on this and the next pages and on page 448. These will further assist a proper understanding of the information given in the table.

It is understood that the official report of the dynamometer reading, and other tests, carried out in connection with the trials will not be available for some time, so that as yet little can be said in reference to the performances of the various models. On the whole, however, the results were satisfactory and there were no really serious breakdowns. The weather throughout was fairly favourable, and did not at any time interfere with the programme, but rain made the heavy land somewhat stodgy. A very large number of spectators attended the trials, and there is little doubt but that they have been of considerable educational value. The Society of Motor Manufacturers and Traders is to be congratulated on their enterprise in organising the meeting. The following notes give information in reference to the details of the majority of the tractors which attended.

The Austin Tractor.

In the Austin tractor the engine and gear case form the frame of the machine, and the design generally has a very clean and neat appearance. The engine is a 4-cylinder cast-iron block with detachable head. The crankshaft is supported in five bearings. The cooling is by thermo syphon, with the radiator in front. The front axle is attached to the frame by a patented centre pivot, and is sprung on a horizontal spiral spring working through a bell crank lever. The lubrication is force feed. The bevel gearing is mounted on the first motion shaft, and the final drive is by spur gearing carried on Timkin bearings. There are two independent road wheel brakes, one on each wheel. The steering is of motor car type, through worm wheel and sector. A draw bar pull of 3,000 lb. is claimed. The control gears are well arranged. The wheel base is 5 ft. 8 in. and track 4 ft. The machine requires a headland of about 8 yards when ploughing with a three-furrow plough. A view of this tractor is given in Fig. 13 on this page.

The Blackstone.

This was the only machine shown which could be converted by the user to run either on a creeper track or road wheels. The change from one to the other is a shop job, demanding a mechanic, and takes about 8 hours. This feature of the machine is a great advantage as on some farms both types of machine are desirable. The design is well thought out and lends itself extremely well to the change over. The engine is a three-cylinder vertical, with force feed lubrication and overhead valves. It is fitted with a compressed air starter, the air pump being driven by an eccentric on the crankshaft. The compressed air is used for starting and fuel injection at a pressure of 300 lb. per square inch. The camshaft carries two sets of cam, so that the engine may be run in either direction. The gear-box, which carries three forward speeds and a reverse, is mounted in a box bolted direct to the engine, which together form the main frame of the power unit. The creeper track is mounted upon a separate frame, and is 8 in. wide, 52 in. in contact with the ground. Both machines have a workmanlike appearance, and these tractors will no doubt have great advantages where the wheels and track are used at different periods of the year. The machine set up as a creeper is shown in Fig. 1 on Plate XXIV.

The Emerson Tractor.

The Emerson tractor model A.A. is a workmanlike machine and is mounted in a channel frame, the road wheels being driven by worm gearing through a bevel differential. It is provided with two forward speeds and a reverse. The radiator is set at the front of the frame and the whole engine enclosed by a bonnet similar to motor car practice. The driver is placed well behind the rear axle and draw bar, so arranged that the tractor ran with four wheels on the unploughed land. The makers claim high efficiency and low fuel consumption. Certainly the machine ran well and appeared efficient. The machine is shown in Fig. 2 on Plate XXIV.

The F.I.A.T.

This is a very clean-looking workmanlike job, the engine and gear case forming the frame of the machine. The final drive is through worm gearing surrounding a bevel differential. The driver is seated over the centre of the back axle and the controls are arranged precisely similar to those usually adopted in motor car practice. The tractor has a high ground clearance, which is useful in certain districts. All the running machinery is well encased and the power unit largely follows the F.I.A.T. motor car construction.

The Fordson Tractor.

The frame of this machine is formed by the engine and gear case, and the radiator is mounted in front and the fuel tank extends over the top of the engine. The detail of the construction has been very well thought out, and the whole machine has a pleasing appearance. The engine is a four-cylinder cast together, having a loose combustion head for the cylinders. The carburettor draws its air through water in a specially arranged air washer. Three speeds and one reverse are provided. The gear-box is driven by bevel gearing through a multiple disc clutch running in oil. The steering is by bevel pinion and sector. The driver's seat is fitted in the centre directly behind the steering wheel. The final drive is through worm wheel, which surrounds the differential. We illustrate the machine in Fig. 14 on this page.

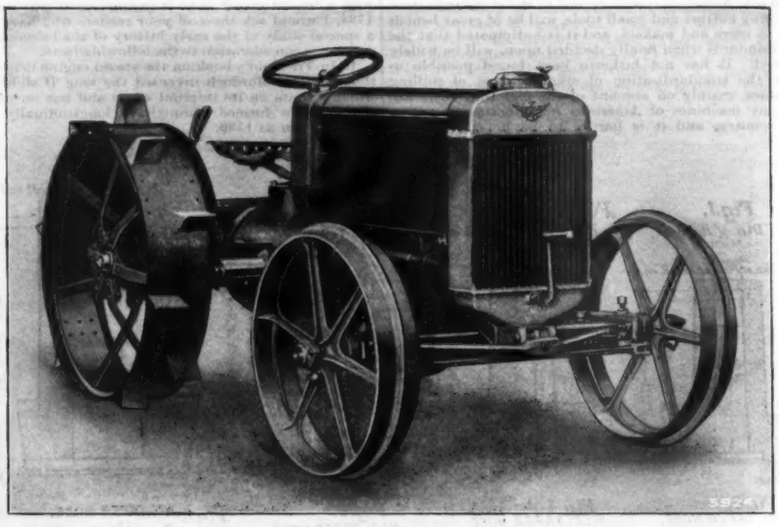


Fig. 13. The 25-H.P. Austin Tractor.

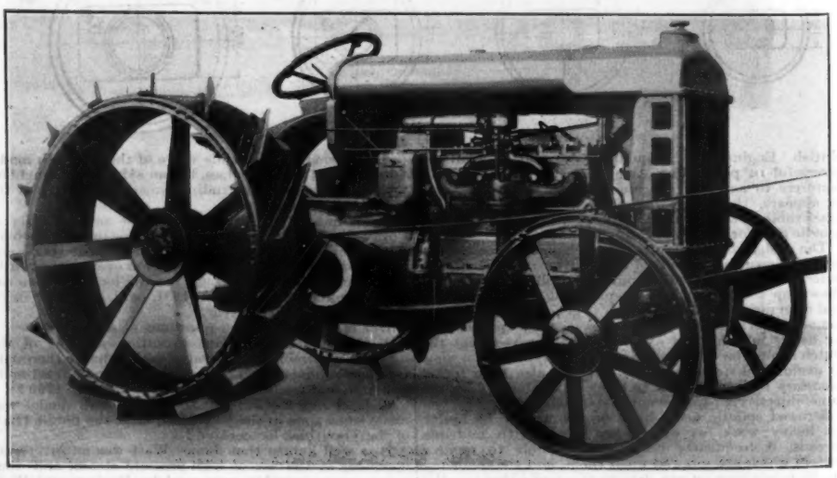


Fig. 14. The 22-H.P. Fordson Tractor.

The Garner Tractor.

The Garner is a very interesting and well-designed tractor, with the detail carefully thought out. The makers claim a draw bar pull on the low gear in the neighbourhood of 3,500 lb., and certainly the machine appears very powerful for its size and weight. The power unit forms the frame and the final drive is by worm wheel mounted on to the live differential axles. The engine has its cylinders cast together with a detachable head. The gear-box is driven through a drive plate clutch operated by a foot pedal. It carries three speeds and reverse mounted on roller bearings; the brakes are internal expanding, acting direct on the rear wheels through pedals. These pedals for the foot pad are hinged and carry a pawl which engages with a fixed notched segment to hold the brake on, and is easily tripped by tilting the foot pad on the pedal. The driver's seat is mounted upon a socket so that it can be readily swung out of the way when the driver wishes to stand to negotiate a difficult piece of shunting. Messrs. Garner have got a specially clever attachment for holding the spuds and other gripping devices to the surface of the road wheels. They supply a rubber tyre in sections and the attachment is very rapid and secure, and is one that will be much appreciated by the user. It is our intention to publish a full illustrated description of the design of this tractor at an early date.

The Glasgow Tractor.

This tractor is mounted upon three wheels, two in front and one behind, all of which are driven. The frame is formed by the engine and gear case and has a neat appearance. The radiator is mounted at the extreme front and the driver's seat projects behind, overhanging the rear of the machine. The clutch and brakes are controlled by pedals, and the front wheels are steered as in motor car practice. The road wheels are driven by a shaft running the full length down the

near side of the frame. The front axle is attached to the engine case by a bracket and hinge pin, which allows a certain amount of sideways movement to accommodate for inequalities of the ground. The front axle is hollow, as are also the stub axles which swivel in it. The two front wheels are driven by a shaft through bevel gearing which passes through to the centre of the pivot upon which the steering axles hinge. The road wheels are driven by a specially constructed spherical joint. The back road wheel is driven by a bevel gear mounted upon it. It has no differential, but the front wheels are provided with a ratchet, so that the outer wheel can overrun when the vehicle is steered. The engine and the whole outfit looked extremely workmanlike and created a great deal of notice. The tractor was very silent and smooth in its work, and the detail had been well thought out. We propose to illustrate and describe this tractor fully at an early date, and in the meantime publish a general view in Fig. 15 on this page.

International Junior.

This is an entirely new design fitted with a vertical four-cylinder engine, 4-in. bore by 5-in. stroke, governed to run at 1,000 r.p.m. The crank is carried in two bearings and the valves are overhead operated by rocking levers from a cam shaft in the base. The cylinders are cast together, have loose liners and loose

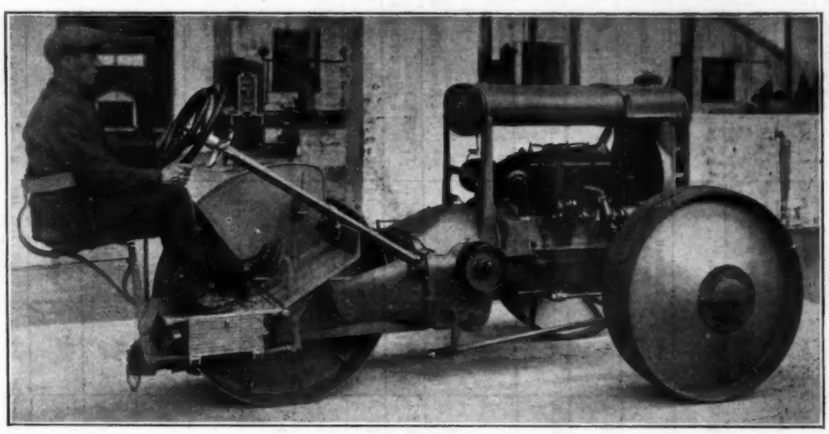


Fig. 15. The 27-H.P. Glasgow Tractor.

head. An Ensign paraffin carburettor is fitted and draws its air through a well-arranged water seal and fine gauze. The gear-box is a separate unit mounted on a channel section frame. The drive is through a multiple disc dry plate clutch and bevels on the first motion shaft. Three speeds forward, 4 m.p.h., 2½ m.p.h., 1½ m.p.h., and a reverse are provided, and the whole is enclosed and runs in oil. The clutch and brake control is by pedal, the brakes acting direct on the road wheels. The final drive to the road wheels is by chain with a bevel differential on the counter shaft. The front axle is hinged in the centre and steering is of the motor car type with worm and sector. The radiator is mounted behind the engine and is very well protected from accidental injury. The cooling is by thermo syphon and the fan screw gear driven. The driver is placed over the back axle and all the controls are well arranged. This machine shows very careful design and all the detail is well thought out. The bearing surfaces appear to be ample and the whole presents a very pleasing appearance. The ploughing work done was good and the machine attracted a great deal of attention. The draw bar pull claimed is 2,500 on the low gear, and there is no doubt that it will be very popular. A view of the machine is given in Fig. 3 on Plate XXIV.

The Illinois Tractor.

This tractor is fitted with a Climax engine, four-cylinder, 5-in. bore, 6½-in. stroke, rated at 40 h.p. at 6 to 800 revolutions. The cylinders have loose heads which can readily be removed for cleaning. A Dixie high-tension magneto, with impulse starter and Stromborg carburettor are fitted. The steering is by worm wheel and segment of automobile type. The front axle is of extra heavy cast steel, and the front road wheels are mounted upon Hyatt roller bearings. The tractor was observed pulling a three-furrow plough in stiff land and appeared to work well.

The Avery Tractor.

The Avery, which is illustrated in Fig. 4 on Plate XXIV, is a large machine having 5-ft. driving wheels and a low speed engine mounted upon an independent frame. The gearing is by spur wheels mostly exposed, and the whole engine slides backwards and forwards on the frame when changing speeds. When ploughing one pair of wheels run at the bottom of the furrow.

The G.O. (General Ordnance).

The G.O. (General Ordnance) has its power unit mounted upon a channel iron frame. The engine is of the usual robust type, having four cylinders 4¼ in. by 5½ in. stroke. The chain speed gear is effected by the friction disc, about 18 in. in diameter, 2 in. face, mounted on an extension of the crankshaft. Two flat steel discs are carried on the sleeve, either of which can be pressed against it. At either end of the driving shaft is mounted a spur pinion, driving a spur wheel to which is attached a sprocket which carries the chain driving the road wheels. The tractor calls for no special comment. The controls are similar to those previously described, and all conveniently arranged to the hand of the driver. The tractor was observed pulling a three-furrow plough in strong land, and the drive seemed ample to develop the full power of the engine.

The Gray.

This tractor is distinctive as the driving wheel is a large drum 54 in. diameter, 54 in. wide. It was fitted with angle iron spuds and driven by a roller chain. It was observed pulling a four-furrow plough in strong land, and the engine seemed well up to its work. The ground was nice and dry and the steering at the headlands appeared facile, although the turning circle required fully 8 yards of headland when ploughing. A view of the machine is given in Fig. 5 on Plate XXIV.

The International Harvester Company's Tractors.

The International Harvester Company had three types of tractors working. The International Junior has already been referred to.

The Mogul is built on traction engine lines and is designed primarily for estate work of hauling and stationary driving. It is fitted with a 30-h.p. two-cylinder horizontal engine 8 in. diameter, 12 in. stroke, governed to run at 550 revolutions. The frame is built up of channel sections and the driver is placed between the rear wheels, which are 60 in. in diameter by 12 in. wide. A canopy is provided over the driver so the whole appearance is not unlike a steam traction engine. The change speed gear runs in oil. Two speeds, 4 m.p.h. and 2 m.p.h. forward and a reverse, are provided. The final drive is by chain running in oil bath. The total weight ready for the land is 4 tons 18 cwts. Water can be injected into the cylinders. The lubrication is by mechanically operated lubricator driven by a ratchet motion from an eccentric on the half-time shaft. Oil pipes are lead to all important bearings. The draw bar pull on the low gear is about 4,500 lb. The cooling is by radiator fitted in front of the machine and the water is pumped from a 10-gallon tank mounted low down. The system is so arranged that when the engine stops the radiator empties, which ensures immunity from damage by frost. This machine is shown in Fig. 6 on Plate XXIV.

The Titan.—This is a medium-sized machine fitted with a two-cylinder horizontal engine 6½ in. by 8 in. stroke, governed to run at 550 revolutions. The general arrangement of the gearing is similar to the Mogul. There are two forward speeds—2¾ m.p.h., 2 m.p.h.—and a reverse gear. The cooling is effected by thermo syphon, and a circular tank is mounted high up over the front axles. There is no radiator, the water being allowed to boil away. The total weight ready for the land is 2 tons 15 cwts., and the draw bar pull is in the neighbourhood of 3,000 lb. on low gear. Fig. 7 on Plate XXV gives a general view of a Titan tractor.

Martin Tractors.

Messrs. The Martin Cultivator Company, Stamford, Lincoln, have entered two tractors. One of the track-laying type, and another of the wheel type, mounted upon four road wheels. The engines of both machines are four-cylinder of vertical type mounted in front with the axis of the crankshaft set at right angles to the road wheels. They are fitted with governors which control the engine speed to 1,000 r.p.m.

The track-laying machine is adapted to work only upon the field, and is self-contained. When ploughing the ploughs are hinged close up to the back of the track and are used as a rudder to steer the machine slightly when travelling over the field. At the headlands the ploughs are lifted clear of the ground by power lift operated by a pedal. The main clutch is operated by hand, the driver pulling the lever towards him to disengage. The steering is effected by moving this same clutch lever to the right or left, thereby disengaging a dog clutch from the sprocket wheel on either track and letting the lever travel forward again and so re-engaging the clutch and applying the power to either track at will. One track runs at the bottom of the furrow and the other track on the unploughed land.

There are three track wheels, the front and rear being mounted upon radius arms and centre upon bars housed on their axles. A screw adjustment is provided for adjusting the relative height of the track wheels to keep the machine level when working on the side of a hill or on the level, and the fulcrum of the radius arms are so placed that this adjustment does not alter the tension of the chain forming the track.

The total gear ratio from the engine to sprocket is 11·9 to 1. The pitch diameter of the track sprocket is 7·26 in. with a pitch of 2½ in.

It is claimed that the tractor can develop a draw bar pull in the neighbourhood of 2,000 lb. The control gears and steering wheel project backwards over the implement upon which is mounted the driver's seat. The control seemed well arranged, and the throttle and clutch levers are in a convenient position to the hand of the driver, making the machine easy to handle.

The headland required when ploughing is about 5 yards wide and the work done by the ploughs was good. The machine pulled three furrows in stiff clay soil, and the engine seemed well up in its work. The weight of the machine with three plough breasts ready for ploughing is 2 tons and the tracks 8 in. wide by 40 in. length on the ground. The two brakes of shoe type, fitted, acting on the sprockets. The belt pulley can be fitted by the removal of one of the chain sprockets. The wheel tractor follows motor vehicle lines and is fitted with two speeds and reverse. The total gear ratio: high gear, 45 to 1; low gear, 80 to 1; reverse, 108 to 1. The final drive is by pinion internal gear to each road wheel. The belt pulley is 18 in. in diameter, 6 in. wide and runs at 450 r.p.m., and is mounted on the first motion shaft. There are four road wheels spring mounted. The rear driving wheels are 51½ in. diameter, 12 in. wide, and the front wheels are 27½ in. diameter, 6 in. wide. Two sets of brakes are fitted, an internal expanding brake on the counter shaft and an external directing type on the rear wheel gear rings.

The change speed is effected by sliding a dog clutch direct into the dogs mounted on the bevel wheel for the top gear or into mesh with a spur wheel on the second motion shaft in a similar way to the back gears of a lathe. The frame is of channel section and the back axle is stationary. Squares are fastened to it by set screws where it passes through malleable iron horn blocks, which also carry a spiral spring upon which they are mounted. The front axle is of square section and attached to a central pivot through a ball joint which allows the axle to tilt when one wheel is raised by uneven ground. The central pivot is housed in a cylindrical casting fixed on the front cross member of the frame. The pivot pins rest on a large ball thrust bearing which is carried on a spiral spring. The steering is of traction engine type by chains wound on to a cross shaft. The main clutch is a cone 18 in. in diameter lined with ferrode. There are two universal joints, each made of three leather discs, which permit of sufficient longitudinal motion to withdraw the clutch. Two wheels run in the furrow when ploughing. The tractor is designed to meet the requirements of the Motor Car Act for haulage on roads. The tractive effort is claimed to be well over 3,000 lb. at a speed of 2 m.p.h. on low gear. A winding drum with 50 yards of ½ in. diameter wire rope is fitted, controlled by the main clutch run through the differential as is usual in traction engine practice. The whole appears to be a workmanlike job. The driver is placed well over the back axle, from which position he is in easy reach of the control gears mounted on the ploughs.

TABLE I.—PARTICULARS OF AGRICULTURAL TRACTORS ENTERED FOR THE TRIALS NEAR LINCOLN OF THE SOCIETY OF MOTOR MANUFACTURERS AND TRADERS.

Name.	Address of Agent or Maker.	Where Made.	Engine.					Forward Speed.	Reverse.	Final Drive.	Weight Ready to Plough.	Road Wheels.			Driving Pulley.			Price.	Remarks.
			No. of Cyls.	Bore.	Stroke	Revs.	If Fitted with Gov.					Number.	Size in Inches. Front.	Size in Inches. Back.	Size.	Revs.	Brakes.		
		GROUP I.						m.p.h.	m.p.h.		tons cwt.				in.			£	
Allday, Mark II, 30 h.p.	Allday and Onions, Birmingham	Birmingham	4	4 7/8	6½	900	Yes	Three: 5, 2½, 1¼	Two	Chain	3 0	2 Front, 2 Rear driving	30 × 6	60 × 10	11¼ × 6½	730	2	630	Three machines entered.
Austin, 25 h.p.	Austin Motor Co., Birmingham	Birmingham	4	3½	5	1,200	Yes	Two: 4½, 2½	Two	Spur	1 8	2 Front, 2 Rear driving	30 × 6	42 × 10	24 × 6	360	2	300	Three machines entered.
Blackstone, 25 h.p.	Blackstone and Co., Stamford	Stamford	3	5	6½	750	Yes	Three	One	Internal spur	—	2 Front, 2 Rear driving	30 × 4½	42 × 10	12 × 6	750	1	500	Not mounted on springs. One entered.
Emerson, 25 h.p.	Melchior Armstrong and Desseau, 27, Maddox-street, Regent-street, W. 1	—	4	4½	5	900	Yes	Two: 2·32, 1·79	One: 1·39	Enclosed spur gear	—	2 Front, 2 Rear driving	36 × 6	54 × 10	12 × 6½	900	1	446	One entered.
F.I.A.T., 35 h.p.	F.I.A.T. Motors, Ltd., 5, Albemarle-street, W. 1	Italy	4	4	7	900	Yes	Three: 3½, 2½, 1½	One: 1½	Worm and wheel	1 8	2 Front, 2 Rear driving	32 × 5	51 × 11·8	14½ × 6½	550	1	—	Two entered.
Fordson, 22 h.p.	Henry Ford and Son, Ltd., Cork, Ireland	U.S.A.	4	4	5	1,000	No	Three: 6½, 2½, 1½	2½	Worm and worm wheel	1 5½	2 Front, 2 Rear driving	27 × 5½	42 × 12	—	—	—	280	Three entered.
Garner, 27 h.p.	Henry Garner, Moseley Works, Birmingham	U.S.A.	4	4½	5½	1,200	Yes	Three	One	Worm and wheel	1 15½	2 Front, 2 Rear driving	13 × 4	40 × 10	8 × 8	950	2	385	Two entered.
Glasgow, 27 h.p.	D. L. Motor Manufacturing Co., Motherwell	Scotland	4	4½	5½	1,100	Yes	Two: 4, 2	1½	Bevel pinions and spur gears	1 16	2 Front, 1 Rear, all drivers	39 × 9	39 × 12	9 × 5	1,100	1	450	One entered.
International Junior, 22·5 h.p.	International Harvester Co., 80, Finsbury Pavement, London, E.C. 2	U.S.A.	4	4	5	1,000	Yes	Three: 4, 2½, 1½	2½	Chain	1 16	2 Front, 2 Rear driving	32 × 4	40 × 12	12½ × 8½	600	2	300	Two entered.
Wallis, Junior, 30 h.p.	Ancona Motor Co., Ltd., 78-82, Brompton-road, London, S.W. 1	—	4	4½	5½	900	Yes	Two: 4, 2½	One	Enclosed spur gearing to live axle	1 10	1 Front, 2 Rear driving	30 × 8	48 × 12	18 × 6	430	1	420	Three entered.
Weeks	W. Weeks and Son, Ltd., Perseverance Iron Works, Maidstone	—	4	4½	5½	900	Yes	Three: 5, 2½, 1½	1½	Pinion and gearing, each road wheel	1 13	2 Front, 2 Rear driving	30 × 5	40 × 10	—	—	2	400	One entered.
Illinois, 40 h.p.	N. W. Simpson, Park Garage, Moseley, Birmingham	—	4	5	6½	800	Yes	Three: 4½, 2½, 1½	1½	Enclosed spur gears to live axles	2 8	2 Front, 2 Rear driving	34 × 5	54 × 10	14 × 8½	600	2	595	One entered.
		GROUP II.																	
Avery, 28 h.p.	R. A. Lister and Co., Dursley, Gloucester	U.S.A.	4	4⅞	7	700	Yes	Two: 4½, 2½	2½	Spur	3 5	2 Front, 2 Rear driving	36 × 6	60 × 12	16 × 7½	700	3	500	One entered.
Case, 18 h.p.	J. I. Case Threshing Machine Co., Racine, Wisconsin, U.S.A.	U.S.A.	4	3⅞	5	1,050	Yes	Two: 3½, 2½	2½	Enclosed spur	1 13½	2 Front, 2 Rear driving	30 × 6	40 × 9	14½ × 5½	1,050	1	375	Did not compete
Case, 27 h.p.	J. I. Case Threshing Machine Co., Racine, Wisconsin, U.S.A.	U.S.A.	4	4½	6	900	Yes	Two: 3½, 2½	2½	Internal enclosed spur	2 12½	2 Front, 2 Rear driving	32 × 6	52 × 12	16 × 6½	900	1	475	Did not compete.
G.O., 32 h.p.	A. Stockwell, 43, Lennox House, Norfolk-street, Strand, W.C. 2	U.S.A.	4	4½	5½	1,000	Yes	Six: 3·9, 3·63, 3·43, 3·2, 2·94, 2·5	The same	Spur to live axle	1 17½	2 Front, 2 Rear driving	30 × 5½	46 × 10	10 × 6	920 to 1,425	2	480	One entered.
Gray, 36 h.p.	American Tractor Co., 11-13, Avenue du Bel Air, Paris	U.S.A.	4	4½	6½	850	Yes	Two: 2½, 2½	2½	Roller chain	2 15½	2 Front and wide rear 1 driving drum	40 × 8	54 × 54	11 × 7	900	2	600	One entered.
Mogul, 30 h.p.	International Harvester Co., 80, Finsbury Pavement, London, E.C. 2	U.S.A.	2	8	12	550	Yes	Two: 4, 2	2	Chain	4 18	2 Front, 2 Rear driving	40 × 6	60 × 12	19 × 9	550	1	580	Two entered.
Titan, 25 h.p.	International Harvester Co., 80, Finsbury Pavement, London, E.C. 2	U.S.A.	2	6½	8	800	Yes	Two: 2½, 2	2	Chain	3 5	2 Front, 2 Rear driving	36 × 5½	54 × 10	20 × 8½	500	2	410	Three entered.
Martin, 28 h.p.	Martin Cultivator Co., Stamford, Lincs.	Stamford	4	4½	5½	1,000	Yes	Two: 3½, 2	1½	Pinion and internal gear to each gear wheel	2 10	2 Front, 2 Rear driving	27½ × 6	51½ × 12	18 × 6	448	2	450	One entered.
Omnitractor, 35 h.p.	Omnitractor Syndicate, 18-19, Great St. Helens, London, E.C.	England	2	6½	9	750	Yes	Two: 4½, 2½	2½	Spur wheels on rear wheels	3 12	2 Front, 2 Rear driving	42 × 6	60 × 16	15 × 6	750	2	650	One entered.
Overtime, 28 h.p.	Overtime Farm Tractor Co., 124, Minories, Aldgate, E. 1	U.S.A.	2	6½	7	700	Yes	Two: 3, 2½	1½	Pinion and internal gear	2 2	2 Front, 2 Rear driving	28 × 5	52 × 10	14 × 8	700	1	368	One entered.

TABLE I (*continued*).—PARTICULARS OF AGRICULTURAL TRACTORS ENTERED FOR THE TRIALS NEAR LINCOLN OF THE SOCIETY OF MOTOR MANUFACTURERS AND TRADERS.

Name.	Address of Agent or Maker.	Where Made.	Engine.					Forward Speed.	Reverse.	Final Drive.	Weight Ready to Plough.	Road Wheels.			Driving Pulley.			Price.	Remarks.
			No. of Cyls.	Bore.	Stroke	Revs.	If Fitted with Gov.					Number.	Size in Inches. Front.	Size in Inches. Back.	Size.	Revs.	Brakes.		
	GROUP II—*continued.*							m.p.h.	m.p.h.		tons.cwt.				in.			£	
Pick, 30 h.p.	Pick Motor Co., Stamford, Lincs.	Stamford ..	4	4¾	5	800	Yes	Nine, varying from : 4½ to 1½	Nine, varying from : 3¾ to 1¾	Roller chain and spur wheels	2 4	2 Front, 2 Rear driving	30 × 5	30 × 6	—	—	1	550	One entered.
Santler, 25 h.p. ..	G. Santler and Co., Malvernia Works, Malvern, Lincs.	Malvern ..	2	6	7	800	Yes	Two	The same	Spur gearing to driving wheels	3 6	2 Driving middle of machine, 1 each end supporting plough	—	—	No belt pulley	—	—	550	Did not compete.
Saunderson, 25 h.p. ..	Saunderson Tractor Co., Elstow Works, Bedford	—	2	5½	8	750	Yes	Three : 4½, 2·16, 1·54	2·16	Spur gears to rear wheels	2 12	2 Front, 2 Rear driving	30 × 10	48 ×10	12 × 7	750	1	510	Three entered.
Whiting Bull	—	—	2	5½	7	750	Yes	2·41	The same	Bevel pinion and ring in one rear driving wheel	2 10	1 Front, 2 Rear driving	30 × 6	40 × 8	12 × 6½	750	1	395	One entered.
	GROUP III.																		
Crawley, 30 h.p. ..	Crawley Agrimotors, Ltd., Saffon Works, Essex	Essex.. ..	4	4¼	5½	1,000	Yes	Two	One	Enclosed spur gearing	2 1	2. Third wheel when machine required as tractor	48 × 8	—	14 × 16	500	1	500	One entered.
Maskell, 25 h.p. ..	J. W. Maskell, Leggatt's Farm, Tillingham, Southminster, Essex	Essex.. ..	4	4	5	1,200	Yes	Two	One	—	1 8	Driving wheel, idle wheel offside, trailing wheel	Driving wheel 36 × 20	Trailing wheel, idle wheel 32 × 6	—	—	2	400	One entered.
Moline, Type D, 25 h.p.	Motrac Engineering Co., Hazlett House, Southampton Buildings, W.C. 2	—	4	3½	5	1,200	Yes	Two	One	Spur gears to rear wheels	2 1	2	52 × 8	—	9 × 6½	1,200	1	450	Three entered.
	GROUP IV.																		
Blackstone, 25 h.p. ..	Blackstone and Co., Stamford ..	Stamford ..	3	5	6½	750	Yes	Three	One	Spur	2 5	Two tracks ..	7 in. wide 52 in. cont	act with ground	12 × 6	750	1	500	Not spring mounted. One entered.
Clayton, 35 h.p. ..	Clayton and Shuttleworth, Lincoln	Lincoln ..	4	4¾	5½	1,000	Yes	Two : 4, 2 ..	3	—	2 16	Two tracks ..	14 in. wid 5 ft. 11½ i	n. contact	7½ × 8 with ground	1,000	—	650	One entered.
Cleveland, 21 h.p. ..	H. G. Burford, 16, Regent-street, S.W. 1	U.S.A. ..	4	3¾	5½	1,200	Yes	One	One	Spur	1 9	Two tracks ..	6½ in. wid 42 in. cont	act with ground	8 × 6	1,200	1	397	Three entered.
Martin, 28 h.p. ..	Martin Cultivator Co., Stamford, Lincs.	Stamford ..	4	4½	5½	1,000	Yes	Two : 3½, 2 ..	1½	Pinion and internal gear each rear wheel	2 0	Two tracks ..	4 in. wide 40 in. cont	act with ground	—	—	2	400	One entered.
	GROUP V.																		
Mann	Mann Patent Steam Cart and Wagon Co., Pepper-road, Hunslet, Leeds	Leeds.. ..	2	4	6¾	300	Yes	Two : 5, 2½ ..	Two : 5, 2½	Spur gears ..	5 0	2 Front, 2 Rear driving	36 × 8	51 × 20	30 × 6	300	2	825	One entered.
Summerscales ..	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Did not arrive.

The wheeled Martin tractor is illustrated in Figs. 16 and 17 on page 448.

"Saunderson" Tractor.

Messrs. Saunderson exhibit a new model very much on the same lines as before. The engine, however, has been re-designed. It is two-cylinder vertical set across the channel frame. The cylinders are 5½ in. diameter by 8 in. stroke. The crankshaft has three bearings and carries a heavy flywheel forming the driving member of the clutch. The lubrication is force feed by gear pump. The driven member of the clutch carries a spur wheel which meshes with the first motion shaft in the gear-box and carries a belt pulley 12 in. in diameter, 7 in. face. A large spiral tube radiator is set across the frame immediately in front of the engine and the air is circulated by a screw propeller fan driven by belt from the magneto shaft. The water circulation is by thermo syphon. The engine is governed and can be set to run at any speed up to 750 r.p.m. Three forward speeds of 4½ m.p.h., 2·16 m.p.h., 1·54 m.p.h., and one reverse, 2·16 m.p.h., are provided. The shafts run in plain bearings. The box is made oil-tight so that the gears are properly protected and lubricated. The final drive is by spur gear through a bevel differential, mounted close to the off side rear wheel. The rear axle rotates and a locking device is provided for locking the differential, which also carries a winding drum with 50 yards of cable.

The driver's platform extends well over the axle and places him in a very convenient position for both road and field work. The main clutch and brake are pedal-operated and the general arrangement of the control is very good. The front axle is a stamping having jaw ends carrying vertical pins for the stub axles, which rest on short spiral springs. The axle is attached to the frame through a jaw in the centre. This attachment allows one wheel to ride over a high obstacle without straining the frame. The tractor looks a very serviceable machine. The position of the radiator is good as it is well out of the way and so unlikely to be accidentally injured. The driving pulley is conveniently placed and indeed all similar details have been well thought out. The weight of the machine, com-

plete with fuel, &c., ready for the land is 2 ton, 10 cwt. The front wheels are 30 in. diameter. The machine is shown in Fig. 18 on page 448.

The "Crawley" Tractor.

The Crawley, a self-contained machine, was doing good work on heavy land, pulling three furrows with comparative ease. The headlands were only 2 yards wide, demonstrating one of the chief advantages of this type of machine. The controls were well arranged, being brought well to the rear, the driver's seat being mounted on the plough. One wheel was set to run in the furrow. The engine and gear-box are mounted together in a channel frame with the radiator set behind the engine. The centre of gravity is on the line of the road wheel axles so that when the plough is lifted the driver can dismount and swing the whole machine round in any direction. This is a great advantage when tilling fields of irregular shape.

The "Maskell."

The Maskell is self-contained, being practically carried upon one driving wheel, 36 in. diameter, 20 in. wide. An idle wheel is fitted on the off side 32 in. diameter, 6 in. wide, mounted on a radius arm, carrying a worm segment, which is adjusted to keep the tractor level when working on a hill side or other uneven ground. The tractor was pulling a two-furrow plough which was fitted with an ingenious patented arrangement to assist the steering. The plough was drawn by a hinge pin surrounded by a circular rack. The shaft carrying the pinion engaged thereby was continued to the back of the plough and fitted with a steering wheel, so that the direction could be altered using the plough as a rudder. Behind the last plough was mounted a further steering wheel running in the furrow, which was steered by a steering arm, keyed to this vertical shaft upon which it hinged. This arm projected towards the off side and was connected with a link to the frame of the tractor, a similar distance from the trunnion pin, about which the plough hinged on the near side. The object of this device was to aid the steering and keep the tractor straight. A view of the tractor is shown in Fig. 10 on Plate XXV.

The "Moline."

The Moline, which is illustrated in Fig. 11 on Plate XXV, is an interesting two-wheeled self-contained machine fitted with electric self-starter, and electric heated paraffin carburettor, and carried electric lights. The batteries were carried in a box in the side of the frame.

The "Clayton" Tractor.

The Clayton is a high power track machine and was seen ploughing in stiff pasture land pulling a four-furrow separately controlled Ransome plough with ease. The turning at the headlands was particularly good, and the controls well arranged so that the driver had complete control of his machine when turning. The headland required is about 6 yards wide. The engine is by Dorman, of Stafford, having four cylinder 4⅜ in. diameter, 5½ in. stroke, running at 1,000 revolutions. The gear-box, provided with two speeds forward and reverse, is driven by a bevel gearing. Two large cone clutches are provided for driving the tracks, and steering is effected by disengaging these from either track at will. The track is specially well constructed and is hinged on the back gear shaft and connected to the frame at the front end through a transverse laminated spring.

The "Cleveland" Tractor.

The Cleveland has a particularly neat appearance. Its small size and handiness have a very convincing appearance. The engine is of the four-cylinder vertical type, fitted with overhead valves and separate combustion head. The clutch is a single disc type and the track pinions are driven through bevel gearing by spur differential. The steering is effected by two band brakes, one on each differential shaft, and are applied through a vertical steering column and wheel. The track is hinged at the back end and mounted at the front on a transverse laminated spring. There are three idle wheels running on the track which is 6¾ in. wide, 42 in. in contact with the ground. The driver's seat is placed well behind and the controls neatly arranged. The tractor runs completely on the unploughed land, and has a draw bar pull in the neighbourhood of 3,000 lb. This machine is much in favour for work in hop gardens, orchards, &c., where its small size, height and quick turning power enable it to work to great advantage. The machine is shown in Fig. 12 on Plate XXV.

The "Mann" Steam Tractor.

The Mann steam tractor, of which a general view is given in Fig. 19 on page 448, is built on light traction engine lines, with a compound engine mounted direct on the top of a locomotive type boiler. The cylinders are 4 in. and 6½ in. in diameter with 8 in. stroke. The crankshaft, which has the cranks set at 180 deg., is mounted in two bearings housed on the fire box side plate which is carried up for the purpose. There are two spur gear pinions, mounted upon the second motion shaft, which are moved sideways to mesh either with the low or high gears, which provide a speed of 5 m.p.h. and 2½ m.p.h. The engine valve gear is of the Stephenson link type, and the heavy flywheel is solid, 2 ft. 6 in. in diameter, 6 in. face. The boiler is riveted, and lagged with slag wool covered with sheeting. The fire-box and tubes are made of steel. The latter are 1¾ in. in diameter, and the working pressure is 200 lb. to the square inch. The steam is superheated by a coil.

The flywheel is used as a pulley for driving threshing, and other stationary machines, and is very conveniently mounted, allowing ample belt clearance towards the front of the machine. The driver is accommodated on the off-side of the vehicle, in front of the rear driving wheel, and his position is very convenient as it admits of a good clear view of the road, both forwards and backwards, and the engine and the controls are close to his hand. Over the back of the road wheels is mounted the water tank of good capacity, it is sufficient for three hours full load. The fire door is arranged through the side of the fire-box by the driver's feet.

The final drive to the road wheels is through spur gearing which is well shielded by a steel plate providing ample protection against stones and dirt getting into the teeth. The tractor is mounted on four road wheels. The rear driving wheels are 51 in. in diameter, 20 in. wide, fitted with diagonal plates riveted on. The front wheels are 36 in. in diameter, 8 in. wide, and are provided with a detachable tyre either of a flat or tee section. The back axle is continuous and a bevel differential gear is mounted on second lay shaft, and locking gear is provided. The front axle is centrally mounted from a cast steel support carried down from the smoke box. All four wheels are sprung so as to comply with the Motor Car Act. The boiler feed is by a plunger pump eccentric drive from the second motion shaft and an injector is also provided. The machine is very powerful and on the low gear is capable of sustaining a draw bar pull on the land in the neighbourhood of 6,000 lb. at a speed of about 2 m.p.h. The tractor when used for ploughing runs completely upon the unploughed surface of the land, and is capable of hauling a four-furrow plough, ploughing 8 in. deep and 10 in. wide, in stiff clay land.

The steering follows the usual traction engine practice by swivelling the front axle upon a centre trunnion and is separated by winding up a chain on a cross shaft through worm gearing. The engine is provided with governor set to control the engine speed at 300 r.p.m. The weight complete with full load of fuel ready to work on the land is 4½ tons, probably two-thirds of which would be on the rear wheels. The wheel base of the machine is 9 ft., and it requires a headland of 8 yards to turn satisfactorily when ploughing. The tractor is designed to meet the requirements of those farming 400 or more arable acres. It can pull four furrows well in really strong land, but except in dry weather when the ploughing should be done it is perhaps more useful on general purpose work of hauling, threshing, &c. The workmanship was good, and the engine seemed to be well up to its work. No condenser is fitted, but the steam turned into the chimney to provide blast. No winding gear was fitted, but we understand this can be supplied.

The "Eoros" Tractor Unit.

This consists of a pair of pulleys mounted on a circular axle carried in plummer blocks attached to channel irons which in turn are attached to the back of a Ford chassis, from which the rear road wheels have been removed. A small pinion is mounted at each end of the differential shaft, which engage with an internal gearing mounted close up to the rim of the road wheel. This surprising little device was able to pull a two-furrow plough on the low gear in stiff land.

The Mechanical Engineer's Pocket Book.—A copy of the 11th edition of this pocket book, which was originally compiled by the late D. K. Clarke, and has been revised and enlarged by Mr. H. H. P. Powles, A.M.Inst.C.E.,. M.I.M.E., has recently been received. The book contains a vast number of tables, formulæ, rules, and data of use to mechanical, civil and electrical engineers, and covering such matters as weights and measures, weights and strengths of materials, riveted joints, mill gearing, steam engines and boilers, water power, electrical engineering, &c. Although in general the arrangement of the original work has been adhered to, the greater part of the matter has been thoroughly revised and brought up-to-date. Railway and tramway statistics, however, remain as in the previous edition, since the data for revising them are not yet available. The electrical section, which was entirely re-written for the previous edition, also remains the same, but some curves and formulæ relating to the presence of moisture in air have been added in an appendix. The book is published at the price of 7*s.* 6*d.* net by Messrs. Crosby Lockwood and Son, of Stationers' Hall Court, Ludgate-hill, London, E.C. 4.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

Iron and Steel.—Industry is completely overshadowed by the railway strike. Owing to pressure on current output engineering, iron and steel concerns have been unable to build up normal emergency stocks from the restricted d·liveries of the South Yorkshire pits, though coal output has recently improved. Thus Friday night's railway crisis found the bulk of the works with small stocks on hand, in some cases sufficient to last only one to two days. Consequently, several of the leading steel and engineering concerns closed down on Saturday for an indefinite period, including John Brown and Co. Limited, Steel Peech and Tozer, Parkgate Iron Works and William Cooke and Co., Limited. Including those formerly displaced by the moulders' strike, nearly 10,000 iron and steel workers are now idle in the Sheffield district. Unless substantial supplies can be imported by road, it is feared that this paralysis of industry will extend daily, and that unemployment in the course of a week will be widespread. Deliveries of all kinds of material being at a standstill, quotations are nominal. A significant feature of raw material production is that now Government control of furnaces have been removed, Derbyshire makers have cut out basic iron from their list of productions and are turning their attention to better paying qualities. The number of inquiries received for engineering work on export account had shown a distinct improvement, but now that firms are enabled to guarantee delivery to a specific date or even within a specific period new business is passing into other channels, largely America. The shortage of castings owing to the moulders' strike alone is responsible for wide dislocation. Hadfields' foundry, the largest in Sheffield, employing 1,500 hands, has been at a standstill for several weeks.

South Yorkshire Coal Trade.—The market for all kinds of fuels is at sixes and sevens. Practically the whole of the tonnage available has been commandeered for emergency purposes. The maintenance of electricity and household supplies over-rules every other consideration. Merchants are not allowed to deliver more than a ton of fuel per week at any private house, and no delivery may be made to any house which has half a ton in hand. Nominal prices:—Best branch handpicked, 33*s.* to 34*s.*; Barnsley best Silkstone, 33*s.* to 33*s.* 6*d.*; Derbyshire best brights, 31*s.* to 32*s.*; Derbyshire house coal, 28*s.* 6*d.* to 29*s.*; Derbyshire best large nuts, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire small nuts, 27*s.* 6*d.* to 28*s.* 6*d.*; Yorkshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; best slacks, 24*s.* to 25*s.* 6*d.*; nutty, 23*s.* to 24*s.*; smalls, 19*s.* to 20*s.*

Wages in Germany during the War.—A striking instance of the rise in wages in Germany during the war and immediately after it is given by the Berlin High Level Railway Company. Beginning at 0·446 mark per hour in the year 1908, the pay fluctuated a little in the years before the war, averaging 0·52 mark per hour for the years in question, and standing at 50 pfennigs per hour in August, 1914. In 1915 the rise was insignificant, the figure for the year being only 0·533 mark, for 1916 it was 0·56 mark and for 1917 0·796 mark per hour. For 1918, with the eight-hour days, the figure was 1·78 marks per hour, and for 1919, from January 15 it reached 2·14 marks per hour.

New Lapland Iron Ore Deposits.—The Commission appointed to examine into the ore deposits on Swedish State property has just reported that the Vietovara ore deposits, which are located in Jukkasjärci parish, about 20 miles west of Kiennavara, are fit for working. The deposits contain a large proportion of sulphur, but the ore lends itself to the production of a concentrate low in phosphorus and sulphur. The deposits, which were only discovered in August, 1914, extend for a length of some 1,300 m., with two interruptions of 150 m. and 200 m. respectively, and have a breadth varying from 20 m. to 60 m. The sulphur ore seems to be fairly evenly deposited over its whole area, but in some places it appears in a larger proportion. Analyses show only 0·004 per cent. phosphorus. It is not yet possible to form an estimate of the capacity of the deposits, but diamond borings show a depth of ore of 40 m. below its surface.

The Railway Strike and Coal Consumption.—In order to ensure the maintenance of essential supplies of food during the Railway Strike, it may be necessary to suspend entirely the transport of coal. The Board of Trade therefore wish to impress most strongly upon every member of the public that it is his personal duty to cut down his consumption of coal, gas and electricity to the lowest possible limit, so as to conserve the stocks of coal that are available. Further, the Board of Trade announce that Emergency Orders have been issued:—(1) Requiring gas undertakings to manufacture gas in such a way as will enable them to spread the consumption of their supplies of coal over as long a period as possible while still supplying gas of serviceable quality. (2) Requiring the discontinuance of all outside advertisement of display lighting on any premises, and also of any inside advertisement or display lighting in shops after closing thereof. (3) Limiting purchases or deliveries for household consumption to 1 cwt. per week, prohibiting purchases by or deliveries to persons who have more than 10 cwt. in stock, and giving power to Local Fuel Overseers to require registration of all consumers and to cut off supplies of gas or electricity where there is waste.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

The Railway Strike.—The railwaymen's strike, which commenced with startling suddenness last Friday night, has already had far-reaching effects upon the industries of the country, few of which can carry on for more than a very limited time. In the present case many industries in this area have already ceased operations, and trade generally is thoroughly disorganised. Not only are the various industrial firms unable to despatch their goods, but supplies of fuel cannot be obtained, and in the iron and steel trades this has necessitated the closing down of most of the works. Many of the shipbuilding yards here also had to stop because of the impossibility of securing material with which to carry on.

Scotch Steel Trade.—The Scotch steel trade, which has been experiencing the most active conditions during the past few months, has now practically dried up owing to the railway strike. Supplies of fuel in pre-War days were always sufficient to last from two to three weeks, but latterly stocks have only been equal to as many days, with the inevitable result that the majority of the larger steel works had ceased active operations by Tuesday of this week. Orders for material—plates in particular—have recently been pouring in, and yet delivery cannot be promised for several months. The demand is certainly much in excess of present outputs, and so long as this state continues there seems little chance of prices becoming easier. Section mills have recently been doing fairly well, but the demand has not been of a pressing nature, and there has been no delay in deliveries. Makers of black sheets have been kept busy, especially with the demand for the heavier gauges. The export trade has continued quiet, owing to the great requirements of the home consumers. Prices remain firm.

Malleable Iron.—Makers in the West of Scotland have recently been extremely busy with a very pressing demand for supplies. Orders on hand are sufficient to ensure steady employment for some time, and these are mostly on home account. Export trade is very small, owing mainly to the reduced output at the different works, with the unfortunate result that shipment orders cannot be faced.

Scotch Pig Iron Trade.—Active conditions continue in the Scotch pig iron trade, but a more plentiful supply of material is general, and deliveries are better at least than was the case previous to the railway strike. There is more hematite available, which will enable steelmakers to increase output. Export is still limited.

AIRCRAFT IDENTIFICATION BOOK.—A copy of the latest edition of "The Aircraft Identification Book," prepared by Messrs. R. Borlase Matthews and G. T. Clarkson, has recently come to hand. The book contains notes and diagrams which act as a useful guide to the recognition of practically all types and makes of aeroplanes and airships of both British and foreign design. It is published by Messrs. Crosby, Lockwood and Son, of 7, Stationers' Hall Court, London, E.C. 4., and its price is 3*s.* 6*d.* net.

INTERNATIONAL EXHIBITION IN LILLE.—The British Chamber of Commerce, Paris, states that a scheme is on foot and is being supported in the press, with a view to organising an International Exhibition in Lille from April 15 to August 15, 1920, which would group together the manufacturing, commercial and technical elements interested in collaborating in the reconstruction of the devastated areas of the North of France. The exhibition in question should afford a good opportunity for British firms to participate and submit in a practical manner the machinery, installations, building materials, and goods of all nature which they have to offer to help in the great work of reconstruction. They would also be able to come into direct contact with French buyers and have facilities for personally interviewing and appointing agents in the North of France. Mr. H. A. Bell, 11, rue Doudin, Lille, Corresponding Member of the local Committee of the Paris Chamber, will be pleased to answer direct any inquiries interested members of the Chamber may care to make concerning the organisation and arrangements for the contemplated exhibition.

MERCANTILE YEAR BOOK AND DIRECTORY OF EXPORTERS.—The fact that strenuous efforts must now be made to recover and increase our export trade gives more than usual importance to the current issue of this directory. This edition, the publication of which has been unavoidably delayed, will maintain the useful character of previous issues, and is considerably larger than those of the last few years. The section giving information as to Continental firms of Allied and neutral countries, is again included, and its re-appearance will undoubtedly be welcomed by subscribers. The directory contains a list of London exporters arranged in street order, and mentions in each case the goods handled and the ports to which they are shipped. This is followed by a list of importers in British Colonies and foreign countries, showing the class of goods purchased and giving the names of representatives and buying agencies in Europe. An alphabetical list of merchant exporters of London, a classified list of goods shipped from London, and lists of the merchant exporters of Manchester, Liverpool, Glasgow, and other provincial towns, are also included, as well as the list of Continental firms above referred to. The work is edited by Mr. W. Lindley-Jones, F.R.G.S. and is published at the price of 15*s.* net by Messrs. Lindley-Jones and Brother, at 16, St. Helen's-place, Bishopsgate, London, E.C. 3.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

Effect of Railway Strike.—Loading operations at the various South Wales docks have been brought to an almost complete standstill, as a result of the railway strike. Here and there the unloading of general cargoes is proceeding, but, generally, work at the docks is at a standstill. At Cardiff, Penarth and Port Talbot vessels are unable to enter or leave the docks, the dock gatemen being out with the railwaymen, and loading is entirely suspended, as there are no tippers at work. Vessels are still able to leave and enter the Barry, Newport and Swansea docks. There are thousands of tons of coal lying on the dock sidings, and the docks are full of vessels at their berths and in the tiers. In the coalfield on Monday about a quarter of the collieries were at work, but the stoppage is bound to become general soon, as the supply of empty wagons will quickly run out. The export of coal, coke and patent fuel to foreign countries has been stopped, and collieries have also received instructions that they are not to dispose of coal standing in the sidings to inland consumers without the sanction of the Coal and Coke Supplies Committee, as they wish to ensure that the coal is used for work of national importance and for household purposes. The dry dock and ship-repairing establishments so far have not been affected by the strike and, as they are reported to have good stocks of material, it is expected that they will be able to carry on for some days. Naval and Military forces have been drafted into South Wales. Prior to the strike the coal market displayed an easier tendency, supplies being more freely available than for some time past. Admiralty large coals were obtainable from 80*s.* and good Monmouthshire large from 77*s.* 6*d.*, compared with 85*s.* and 82*s.* 6*d.* respectively a week earlier. Smalls were also more freely available on the basis of 60*s.* for the best descriptions, ordinaries from 50*s.*, and inferiors from 37*s.* 6*d.* Coke remained steady from 100*s.* to 105*s.*, and patent fuel was irregular from 75*s.* to 80*s.* Pitwood continued plentiful, with the inquiry inactive and prices from 52*s.* 6*d.* to 55*s.*

Pitwood Workers Demand Increased Pay.—The Bristol Channel pitwood workers have put forward an application for increased pay. The demands will form the subject of negotiations between the employers and the men. The new demands exceed present rates in practically every instance. For discharging and trucking 1*d.* above the present rates are asked, but in regard to discharging bunkers, alleyways, forepeaks, lazarettes, bridge decks and tanks an increase of 1*s.* 2*d.* per ton is asked. The demand is that waiting time rate be advanced from 1*s.* 7*d.* to 2*s.* 6*d.* per hour, and an increase of 1*s.* 4*d.* per ton is asked for dealing with abnormal places.

MAGNESITE.—According to a paper read by C. D. Dolman before the Columbia Section of the American Institute of Mining Engineers, the consumption of magnesite of the United States amounted to 172,591 tons in 1913, and less than 3 per cent. of that bulk was home produce. At present practically all the magnesite is mined in the country, and there are only small imports from Mexico and California. In 1917 the production of the United States had risen to 375,000 tons, being 75,000 tons in excess of the demand, therefore the production of 1918 decreased to 225,000 tons. The change in the position is due to the development of the Californian magnesite deposits and to the discovery of immense deposits in Stevens County, Washington. Dolman is chief chemist to the North-West Magnesite Company at Chewelah, 65 miles north-west of Spokane. These Washington deposits resemble the Austro-Hungarian and Canadian magnesite—which is crystalline, whilst the Greek and Californian magnesites are morphous; but there is much less waste in Washington, one-fifth of the mineral mined being magnesite. Dolman pointed out that the water power and raw materials of the district afford great opportunities for building up important industries.

ARTIFICIAL ATMOSPHERE IN COAL MINES.—The question of charging coal mines with atmospheres poor in oxygen, in order to reduce the dangers of explosions, came up again before the Sydney Section of the Society of Chemical Industry in May last, in connection with a "Note on Explosions in Coal Mines," communicated by Dr. G. Harker. The suggestion of diluting the air in coal mines with a sufficient amount of flue gas was made by Dr. J. Harger some years before the war. Attention had recently been drawn to the matter again by T. J. E. Rhead in his experiments on residual and extinctive atmospheres (Journal of the Society of Chemical Industry, 1918, page 277 T.). Rhead had found that an atmosphere containing 17 per cent. of oxygen would still be able to propagate an explosion, contrary to Harger's opinion. Harker pointed out that the flue gas would, of course, have to be purified of all carbon monoxide before it would be mixed with an air to be breathed, and that would be very difficult; 0·3 per cent. and less of carbon monoxide is sufficient to kill rats in enclosed spaces. Moreover, men cannot work in so poor an atmosphere, though Haldane showed that man can exist for a time in an air containing as little as 12 per cent. of oxygen. It is true that at altitudes of 6,000 ft. the partial pressure of oxygen is reduced to a value corresponding to the 17 per cent. mentioned, but such air does not contain 4 per cent. of carbon dioxide occurring in flue gas. Altogether it hardly appears worth while to discuss Harger's suggestion any further, all the more since most serious mine explosions are coal dust explosions, and are best prevented probably by shale dusting.

NOTICES OF MEETINGS.

THE CERAMIC SOCIETY.—Wednesday and Thursday, October 8 and 9, the autumn meeting of the Refractory Materials Section of this society will be held in the Central School of Science and Technology, Stoke-on-Trent. The following papers will be read and discussed: Wednesday morning, at 11 a.m., Dr. A. Scott on "The Refractory Materials of the North Staffordshire District" Mr. T. Acton, F.S.A., on "Carboniferous Grits of Denbighshire and Flintshire"; Dr. A. Scott, on "Expansion of Silica Bricks"; Mr. H. V. Thompson, M.A., on "Determination of Zirconia"; Dr. H. Chatley, on "Molecular Force and Plasticity of Clays." Wednesday afternoon, at 2.30 p.m., Mr. W. C. Hancock, "Notes on the Influence of Grog in Admixture with Clay"; Dr. L. Bradshaw and Mr. W. Emery, on "The Specific Heat of Refractory Materials"; Mr. W. Emery and Dr. L. Bradshaw, on "Some Comparative Tests of Machine-made and Hand-made Silica Bricks"; Mr. A. S. W. Odelberg, on "Some New Appliances in Ceramics." Thursday morning, at 10.45 a.m., Mr. A. Heath, on an "Excursion to America, Summer 1920." A symposium on Gas Firing will then be opened by Professor T. Gray, in which the following will take part: Messrs. S. T. Wilson, J. H. Singleton, William Leckie, A. Fielding, C. W. Thomas, H. M. Ridge, H. H. Bailey and J. Williamson. On Wednesday afternoon, at 5 p.m., Mr. J. B. Allen will give a demonstration of Vacuum Casting. On Thursday evening, at 7.30 p.m., Professor H. E. Armstrong will deliver a lecture on "Potter's Clays:" this will be open to the public.

THE SOCIETY OF ENGINEERS.—Monday, October 6, 1919, at 5.30 p.m., in the rooms of the Geological Society, Burlington House, W. The proceedings will open at 5 p.m. with a social gathering of members and visitors (tea and light refreshments being provided), after which a paper will be read at 5.30 p.m. on "The Development of Artillery during the War," by Capta'n. M. E. de Jarny, M.Soc.Ing.Civ. (France), Chevalier de la Légion d'Honneur, Croix de Guerre.

AMERICAN FREIGHTS.—We read in *The Iron Age*, New York, that foreign exchange conditions, which have put a damper on export shipments, have caused the Shipping Board to make reductions in ocean rates. Among the rates are quoted 1·50 dols. per 100 lb. on boiler tubes and 1·65 dols. per 100 lb. on wire coils and rods to Havre, Bordeaux, St. Nazaire and Dunkirk. A rate of 1·25 dols, per 100 lb. is made on nickel to Antwerp and Rotterdam, with boiler tubes listed as special. It is expected that other reductions will be made to different European ports. In a revised tariff on shipments from the United States North Atlantic ports to North Africa, Turkey and Red Sea ports, iron and steel stowing up to 20 cub. ft. are given a rate of 1·25 dols. per 100 lb., while articles stowing from 20 cub. ft. to 40 cub. ft. are to pay 1·75 dols. per 100 lb.

THE UNITED STATES NAVY.—The Acting Secretary of the Navy, says *The Iron Age*, under date Washington, September 1, desires an enlarged appropriation. He asks Congress for an additional 18,900,000 dols. for Navy repair and construction work. Two motives have inspired this request. The first is the seriousness of the international situation, including the delicacy of the American-Japanese relations. The second is the fact that unless this additional appropriation is made, work would have to be cut down in many navy yards. "The Chief of Naval Operations, who is charged with the operations of the fleet and with preparation and readiness of plans for its use in war," says the Acting Secretary "has stated that in his professional opinion he considers it important, if not urgent, that every fighting unit of the fleet should be put in fighting condition at the earliest possible moment, and that if the appropriations are not adequate for accomplishing this, steps should be taken to have them augmented to the extent estimated to be necessary. While it is no more important or urgent at this time than when the current appropriations were in the course of making, it cannot be denied that the opinion of the Chief of Naval Operations is fundamentally sound."

IMPORTS OF BRAZIL.—The Federation of British Industries states that coal has always headed the list in imports into Brazil of raw materials, the amount for 1913 being 2,262,348 metric tons, shipped chiefly from Great Britain. In 1917 the total fell to 818,327, and in 1918 to 637,486 metric tons, the bulk being purchased from the United States. Imports of iron and steel decreased from 80,000 metric tons in 1913 to 18,000 in 1917, and 10,000 in 1918. Except in the case of jute and hemp, both raw and manufactured, the decline in imports of textile materials and products has not been so marked. In some cases a partial recovery may be observed on the figures for 1917; but the total tonnage has shrunk from 43,709 metric tons in 1913 to 32,935 in 1917, and to 22,161 in 1918. Imports of machinery presented a large item in pre-war days; in 1913 no less than 120,000 metric tons were imported. But in 1917 the imports had fallen to 27,000, and a year later to 24,000 metric tons. There was, however, in the last year under review, an increase in imports of hydraulic pumps, boilers, tractors, electric dynamos, generators and transformers, spinning machines and looms, and steam, oil and gasoline motors. Thirty aeroplanes and 44·5 metric tons of accessories were imported during 1918, as against one aeroplane and 1·4 metric tons of accessories during 1917, the respective monetary values being 79,368*l.* and 8,091*l.*

MOTOR TRACTORS AT THE LINCOLN TRIALS.

(*For Description, see Page* 442.)

Fig. 16. The 28-H.P. Martin Wheeled Tractor.

Fig. 17. The 28-H.P. Martin Wheeled Tractor.

Fig. 18. Saunderson Tractor

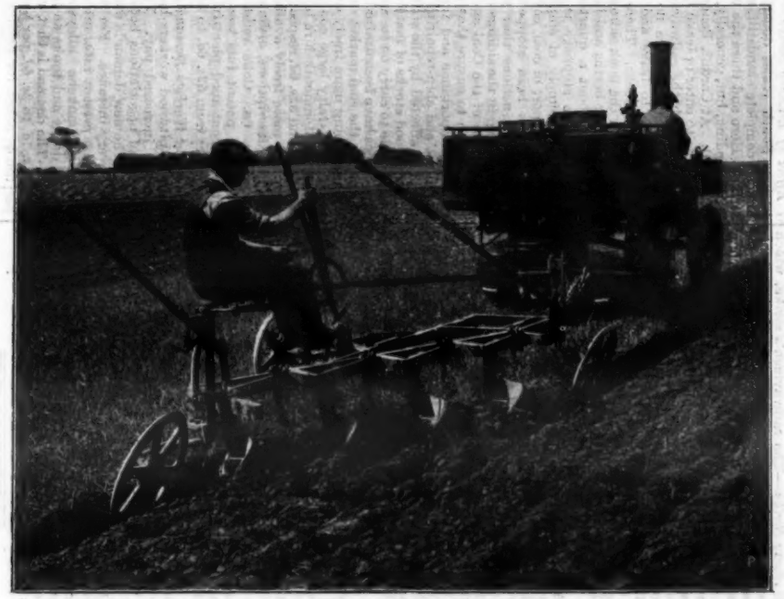


Fig. 19. The Mann Steam Tractor.

PORTABLE MILITARY BRIDGES; THE INGLIS SYSTEM.

(*For Description, see Page* 439.)

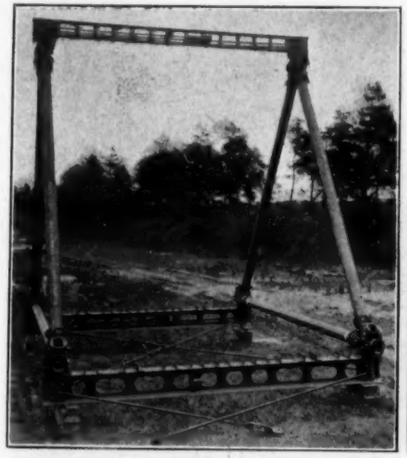


FIG. 16. A BAY OF THE BRIDGE IN SKELETON.

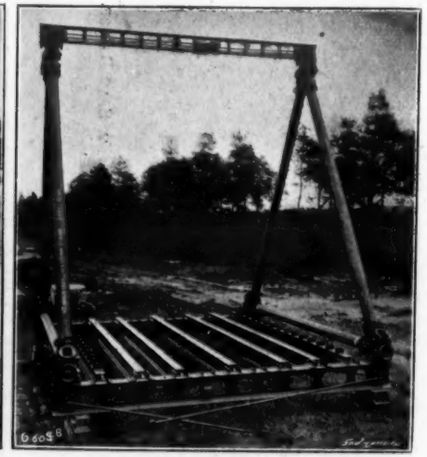


FIG. 17. VIEW SHOWING DECKING.

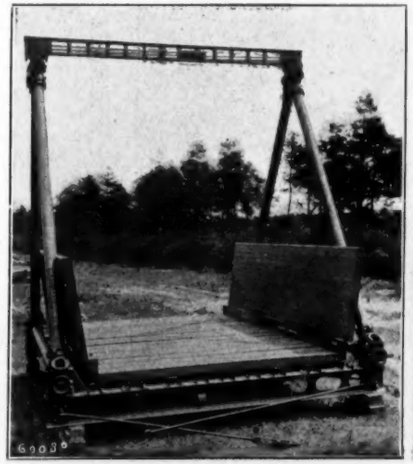


FIG. 18. A BAY COMPLETELY DECKED.

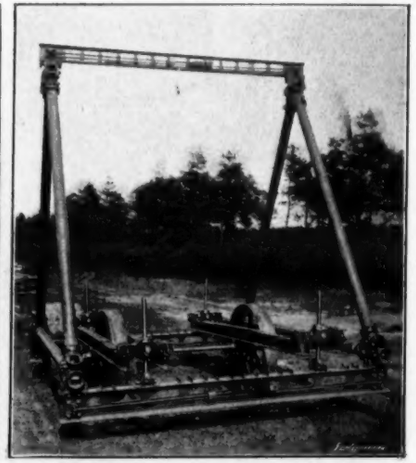


FIG. 19. A BAY MOUNTED ON A TROLLEY.

FIG. 20. ENLARGED BRIDGE 240 FT. IN LENGTH.

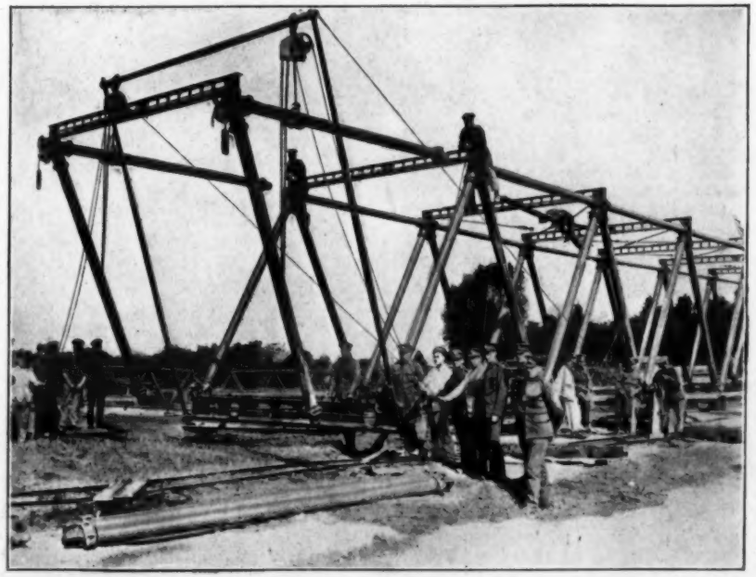


FIG. 21. DERRICK IN POSITION FOR ERECTION OF BRIDGE.

(*To face page* 440.)

PORTABLE MILITARY BRIDGES; THE INGLIS SYSTEM.

(*For Description, see Page* 439.)

Fig. 22. *Articulated Joint at A*

Fig. 23.

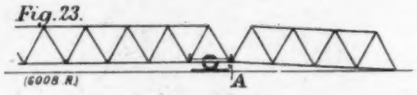


Fig. 24.

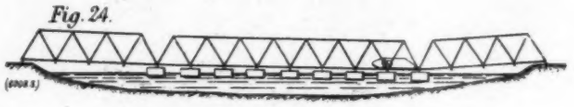


Fig. 25. Pontoon Bridge.

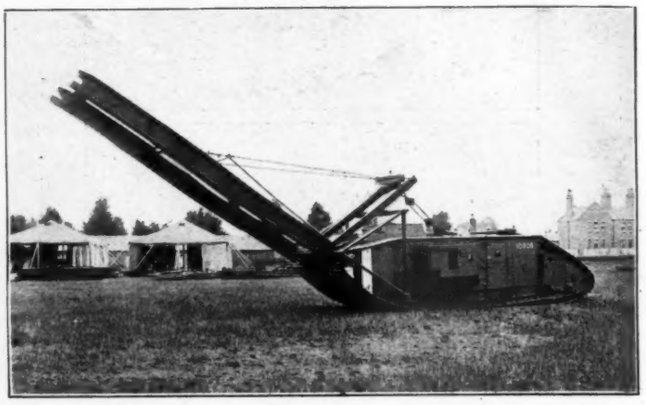


Fig. 28. Tank Carrying 25 Ft. Span Bridge.

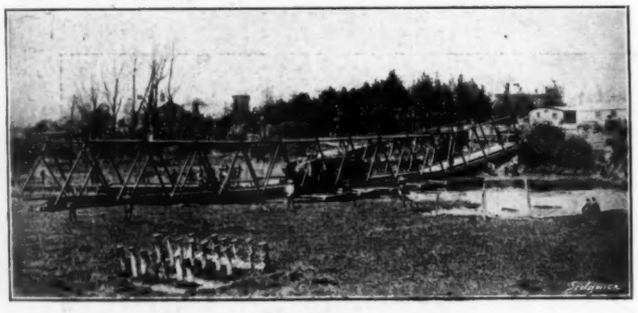


Fig. 26. Pontoon Bridge.

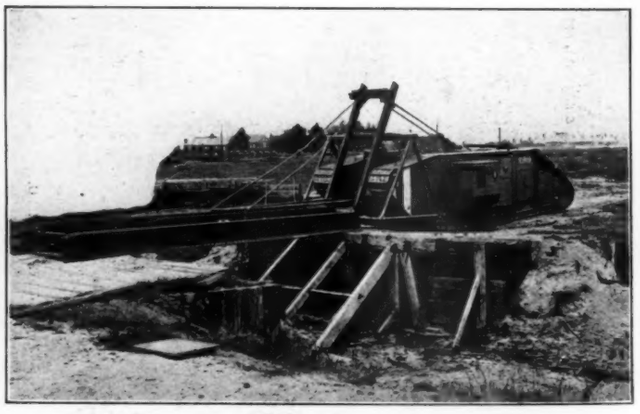


Fig. 29. Tank Depositing 25-Ft. Span Bridge.

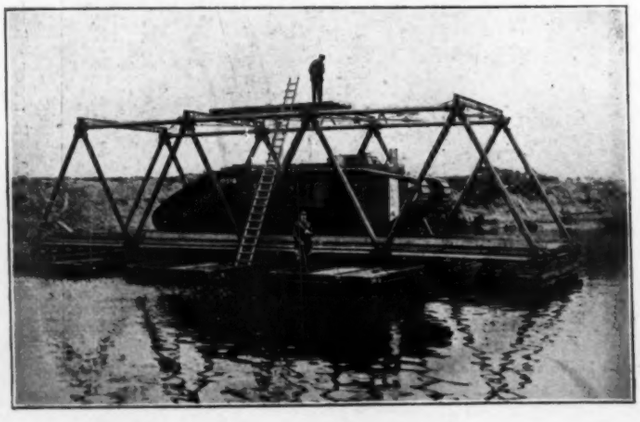


Fig. 27. Tank Ferry.

Fig. 30. The same Tank Crossing the Deposited Bridge.

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MOTOR TRACTORS AT THE LINCOLN TRIALS.

(*For Description, see Page* 442.)

Fig. 1. The Blackstone 25-H.P. Track Laying Tractor.

Fig. 2. 25-H.P. Emerson Tractor with Cockshutt Plough.

Fig. 3. The International Junior 22—25-H.P. Tractor.

Fig. 4. 28 H.P. Avery Tractor with Cockshutt Plough.

Fig. 5. The Gray Tractor.

Fig. 6. The Mogul 30-H.P. Tractor.

(*To face page* 442.)

MOTOR TRACTORS AT THE LINCOLN TRIALS.

(*For Description, see Page* 442.)

FIG. 7. 25-H.P. TITAN TRACTOR WITH SELLAR PLOUGH.

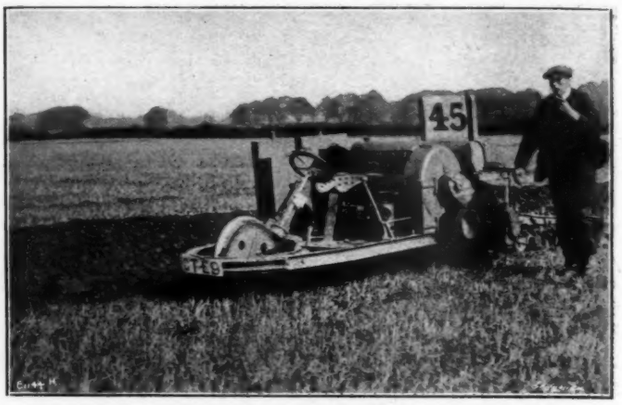

FIG. 8. THE PICK TRACTOR PLOUGH.

FIG. 9 THE WHITING-BULL PARAFFIN TRACTOR.

FIG. 10. THE MASKELL TRACTOR PLOUGH.

FIG. 11. THE MOLINE 25-H.P. TRACTOR.

FIG. 12. THE CLEVELAND 22-H.P. TRACTOR.

(*To face page* 443.)

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ENGINEERING.

FRIDAY, OCTOBER 3, 1919.

DEATH OF MR. B. ALFRED RAWORTH.

ON September 30, 1919, at 6, Wickham-road, Sutton, Surrey, Benjamin Alfred Raworth, Wh.Sc., M.I. Mech. E., Joint Editor of ENGINEERING, Aged 70.

THE STRIKE.

From every point of view the strike declared by the National Union of Railwaymen is regrettable, and perhaps most in the interests of the workers of the country. In the case of some of the serious strikes of the past it was contended that the men got out of hand and forced the executive council to recognise their desire for a stoppage. In this case the strike is "officialled" in the fullest sense of that word, and as it is involving great inconvenience to the whole of the community, and must continue so to do, there is inevitably that absence of public sympathy which after all means, in such disputes, failure for the workers. This public sympathy, we may add, is never withheld when justice is on the side of the men.

In reviewing broadly the position of affairs, we are anxious to do full justice to the railway workers, because in the present temper of the country it is most desirable that criticism should not be one-sided, and that everything should be done to bring all parties to a reasonable view of the state of affairs, especially now that negotiations have been resumed. This cannot be done by attributing motives unless such motives can be fully proved, nor can any exaggeration of the position on one side or the other be serviceable. We are prepared even to believe that the great majority of the rank and file concerned in the dispute have been actuated in their action by economic rather than political reasons.

The railwaymen had an excellent record during the war. For obvious reasons, just as was the case with the men engaged in the engineering trades, they contributed to the trenches a smaller proportion of their number than did other sections of the community, but no discredit attaches to either body of men on this account. Both were doing, at home, work as essential to our success in the war as the men in the fighting line. There was, however, this difference between these two classes of workers at home—whilst those engaged on "munitions" enforced the payment of excessively high wages, the railwaymen did not show anything like the same tendency to exploit the necessities of the nation for their personal advantage. With depleted numbers and with material at a standard lower than the normal they conducted a traffic heavier by tens of thousands of tons and millions of passengers than has ever previously been recorded in the history of our railways. The extraordinarily high takings of the men employed on munitions during the war cannot but have tended to make the railway men dissatisfied even when consideration is given to the various substantial increases of pay ultimately awarded them.

Even an un-skilled or semi-skilled labourer who entered the munition works received at times 10*l.* a week, or even more, and cases have come before the Courts in which it was shown that young lads in their teens were drawing over 6*l.* a week. This resulted from the agreement with the unions concerned in the engineering trades that piece rates should not be cut although the product per man was enormously increased by reason of the suspension of the restrictions of output. The increase in the week's earnings was thus very considerable, and led to a "surplus on working" of many factories rising much above the normal level, even when the price paid by the Government for its shells and the like was reduced below the peace-time prices. It was deemed right that some four-fifths of this increase in the "surplus on working" should be taken over by the State in the form of excess profits duty. No similar rule, however, was applied to the enormously greater excessive collective takings of the men, and it is perhaps not to be wondered at that the railwaymen have come to the conclusion that relative to the remuneration of other classes of workers their position demanded serious consideration and augmented rates of pay. They have accordingly put forward demands, but these, in the opinion of those competent to judge, are far in excess of what the country can afford to meet. The immediate necessity is to bring the value of money back to better proportions, because any addition to wage which cannot be conceded without proportionate addition to cost of living will not bring any relief in the balance sheet of the worker's household. The problem therefore is so to balance the relation of cost of production to selling price as to ensure a reduction in the latter while maintaining wages at the highest possible level.

The Government have proposed as the basis of agreement in connection with railway workers that the standard rate of wage shall be double the pre-war rates, but that in no case should it be less than 40*s.* per week. This is actually an understatement of the result, since the concessions in the rates of payment for night duty, Sunday work and overtime, where those are necessary—and they are almost inevitable in railway work—the actual earnings may be as high as 2·4 times as much as under pre-war conditions. To the proposed standard rate of wage, too, there are added the very substantial bonuses which are to be continued whilst the present high cost of living rules. But what is equally, if not more, important is that no change was to be made in the present rates of pay until after December 31 next.

The men's demand is that the present highest rates paid anywhere shall be taken as the standard basis, with a minimum of 60*s.* per week, which the men's leaders suggested might be reduced if the cost of living fell, but only even then by agreement with the men—an agreement which might not be secured save as a result of an unsuccessful strike. The suddeness of the present strike has, unfortunately, given rise to the view that influences repellent to the great patriotism and commonsense of the British working man have been at work, and further that the railwaymen were not willing to give any consideration to the enormous inconvenience and hardship involved by the sudden cessation, without any notice, of the whole of the railway traffic in the country.

The facts cannot be explained away. The pre-war wages bill of the whole of the railways of the country was 47 million sterling. This was advanced during the war, owing to concessions and bonuses, and if the Government proposals were not accepted the total wage bill would be increased to 114 millions sterling per annum, plus whatever may be paid in the way of bonuses consequent on the high cost of living. The Government contend that to grant the demands made by the men would inevitably necessitate large increases in passenger fares and goods rates. But the representatives of the men contend that the sum required should be confiscated from the shareholders. This alternative is one which no responsible Government could accept. The leaders of the men know quite well that money to-day has only about one-half of its pre-war value, so that the shareholders are now receiving only about one-half as much in remuneration for the use of their capital as was formerly the case, and this is further reduced by the enormous increase in taxation. To reduce still further, or to extinguish, the present very small return on their capital is unquestionably more in the direction of syndicalism, a system by which in effect the men in each trade are to seize the instruments of production created by the ability and enterprise of others and to operate them for their own benefit. Without attempting again any argument on this subject, it may be observed that in practice this scheme would work out very unequally. The provision of the plant and equipment necessary to find work for each railwayman has involved an average capital cost of somewhere about 2,000*l.* The intrinsic value of the property, as measured by the cost of its replacement now, would be nearer 4,000*l.* than

2,000*l.* per head employed. In the manufacturing trades, on the other hand, the corresponding capital cost at pre-war rates has reached from 150*l.* to 200*l.* per head employed, so that under syndicalism the railway men would be endowed with property worth at pre-war rates some 2,000*l.*, whilst the factory hand would receive as his share property worth on the average less than one-tenth of this amount.

Perhaps on the whole the community is to be congratulated on the fact that if a struggle was inevitable that struggle has come now rather than in the depth of winter. A strike then would have increased the difficulties of the situation very appreciably. Moreover, further progress would by then have been made towards normal peace conditions under which the enormous fleet of motor lorries still held by the Government would have been dispersed and disposed of, whereas now these are serving to distribute food supplies. Another cause for congratulation is that the Food Control Department is still in existence, and consequently it is a much more simple matter to arrange for a fair division of the stocks in hand than would have been the case had the strike occurred under pre-war conditions. The Government, we may add, deserve high credit for that organisation which enabled them to call into existence at such short notice the extensive and well-ordered system for the distribution by road motor vehicles of food and other essential supplies. Food so far has been adequately and quickly delivered.

It is, of course, true that even these crumbs of comfort may fail us if the strike is further extended, but as we said at the outset the important factor of success in such cases is the sympathy of the public. This applies particularly to strikes in which the operation of public utility services are impeded, because they hit hardest the "common people"—the wage and salary earners. The wealthy man is not affected to anything like the same extent, as his financial resources come to his aid. Consequently, unless it can be proved to the general public that those on strike have a strong case, and further that all means of arranging matters amicably have been tried exhaustively, there is bound to be a lack of sympathy if not a wave of resentment more or less intense.

As a consequence volunteers soon declare themselves ready to do all they can to take up the work of those on strike, and that is what has happened to-day with results which are eminently satisfactory. Railway work demands intelligence as well as experience, if the highest efficiency is to be achieved, but efficiency is a relative term, and if the work can be done by volunteers with a satisfactory measure of safety, then it is vastly more acceptable than the absolute cessation of all travelling facilities. For the reasons we have stated it is thus certain that regret at the action of the men must be entertained in connection with this strike by all who support the sound principles of trade unionism and their application with due regard to the common-weal.

SCIENTIFIC MANAGEMENT IN AN IRON FOUNDRY.

A considerable amount of literature, dealing with the application of scientific management to various industries in the United States of America, has been published. So little is said about what is being, and has been, accomplished in this country, that it might well be considered that the movement is almost stagnant here. We are liable, as a nation, to underrate our own efforts and to over-estimate the value of the organisations of competitive industrial states. As a matter of fact, signs are not lacking that, in the near future, the movement of scientific management will have achieved in our industries as great application as it has in the United States of America. The vast amount of American propaganda, conducted often by efficiency experts, is misleading, inasmuch as the movement in America is not so generally applied as these advocates would give our engineers to believe.

In all matters where new first principles are involved, where old-established methods—responsible on their part for considerable past success—are passed over or are even made the subject of minute examination and proved wanting, theoretical argument can only expect success after hard effort. The old adage that a small amount of practice is worth a great deal of theory in such cases is very true. Gradually, however, in this country practical experience is accumulating, and it behoves engineers carefully to watch such developments, giving credit where it is due. To this end a recent pamphlet issued by the Industrial Fatigue Research Board entitled "A Study of Improved Methods in an Iron Foundry," gives in simple language and concise form the manner and the results of the application of scientific management to an iron foundry. Moreover, as indicating the extreme value of this contribution to the literature on this subject, and as testimony to the efforts of British industries, it should be stated that the data given are not based on short periods of working, but are deduced from three full years of operation during the war period (August, 1915, to 1918).

The foundry in question—The Derby Foundry Company, Limited, of Derby—was concerned with the casting and moulding of hand grenades, and the casting, moulding and machining of fuse hole plugs. The authorities estimated the output to be 3,000 per week, but by August, 1916, 20,000 weekly were actually being delivered. Possibly the original estimate of 3,000 was too low, but, it is stated that a similar works with more plant were only turning out 5,000 weekly.

It has often been stated by those who were perhaps not too anxious to undertake the experiment of introducing scientific management on the Taylor system, that the objections which would be raised by the men and by their trades unions would be prohibitive and would absolutely preclude success in this country in most cases. In this connection, therefore, it is exceedingly interesting to note that the firm in question first of all consulted their men, and that throughout the whole time of inauguration and development of this system, little opposition was experienced, and that only in regard to minor points about some of which details are given. As we believe to be thoroughly essential to the obtaining of the full benefits of the system of scientific management, the preliminary investigations commenced with the training of the operators under a system of "motion study," where the various jobs were split up into their elemental units, each of which was studied with the aid of a stop watch, in order to eliminate superfluous movements and to arrange the appliances on the best scheme for maximum production. Combinations of such movements were regularly evolved. Each job had its typewritten card of instructions in regard to the movements necessary for each process, equated to the times requisite for their performance. These instructions were given with the minute detail consequent upon the original motion study which had been carried out and which indicated, for instance, whether the right or the left hand should be used.

It is estimated that of the great improvement in output achieved 90 per cent. may be attributed to increased human efficiency. In the machine shop the even greater increase in total production than in other departments was largely due—though by no means entirely so—to improved efficiency of the machines. Naturally the duration of the training period of the worker varied with the personal equation. One of the most successful pupils, it is recorded, was a man who could neither read nor write, but, as his memory was developed to an extent considerably above the average, he could easily commit to memory the instructions received, and it was found that his period of training could thereby be considerably curtailed.

Each operator received separate instructions. Simultaneously with the commencing of training, the hours were reduced from 54 to 48 and were continued unchanged at 48 hours per week.

In conjunction with this application of scientific management an improved system of payment was evolved. During the training period workers received 25 per cent. above the standard rate. So soon as the operator showed that the standard output could be maintained, he was put on to differential piecework, which is pure piecework, with the difference that the greater the number of pieces turned out or the greater the amount of work done per day or per unit of time, the higher the piecework price per unit of work. This system, of course, has been advocated and adopted to some extent for repetition work in America, and has the great advantage of offering a strong incentive towards maintaining the highest possible standard of efficiency. That this system is fair cannot be denied, since the greater the number of units of work performed, the less the rate to be allowed for certain overhead charges, &c., per unit, and therefore the higher the price per unit which can be paid as direct wages.

The disadvantages are such, however, that unless careful study, entailed by following fully the system of scientific management, be the preliminary step to the fixing of piecework prices, these inevitably become so haphazard as to cause in some cases too high earnings to be made, and in others, too low.

Differential piecework necessitates motion study. The system adopted in this case for increasing the piece rate per unit of work was such that workers of exceptional ability could turn out sufficient work to increase the price per piece by about 25 per cent. above the standard piecework price. The possibilities of increase of earnings resulting from this application of scientific management may be shown by comparing the figures for a certain worker for six consecutive weeks prior to the introduction of the system, with those for another six consecutive weeks in 1918. The increase in earnings in this case was practically 200 per cent., neglecting, of course, in this comparison, all war bonuses and war advances. As usual, the assurance was given that the piecework prices would not be "cut." The overall figures, indicating the increase in production achieved by scientific management, in this case, have already been given. To deal with the specific case, a job which, before the war, gave an average output of 48 per day of 10 hours, was standardised under the system of motion study, at an output of 147 per day of $8\frac{3}{4}$ hours, meaning an increase of 284 per cent. per day, or 350 per cent. per hour, which was regularly surpassed by trained adult workers.

In the early stages of the application of this system, strong protests from the workers as to the impossibility of achieving the standard, were not lacking. However, the men were willing to be trained in their work, and the results of the training rapidly dissipated these fears.

It should again be emphasised that, in this case, the nature of the work was extremely favourable to the experiment, the successful results of which are so well detailed in the pamphlet already mentioned. The work was repetition work of the truest type, the product did not change throughout the period under review. The demand was greater than could be met and was guaranteed by war conditions. The thought must arise that, had such methods been more generally employed in the industries of this country during the last few years, more particularly by those which were concerned with the production of the great mass of munitions of war, constituting essentially repetition work, an enormous saving in time, labour and the nation's capital, would have been affected.

Now that we are turning to the conversion of our swords into ploughshares in full face of the severe economic conditions resulting from the unparalleled expenditure of money and of energy throughout the war, any means towards increased efficiency which can be applied should be grasped. The difficulties should boldly be faced, and, although the first principles of scientific management may be considered to be most applicable to repetition work, it will generally be found on analysis that there is a very large amount of suitable work in many of our great peace industries. Experience of such methods as we have described would probably lead to extension of effort and broader application.

Tin Plate in Japan.—According to *The Iron Age*, New York, it is reported that the Yamata State Steel Works, Kyushu, have for some time past been carrying on experimental work in the manufacture of tin plate, and the results are so promising that commercial manufacture is soon to be started and the product put upon the market.

THE LATE MR. B. ALFRED RAWORTH.

It is with very deep and sincere regret we record the death, on Tuesday last, at Sutton, Surrey, after a severe illness lasting many months, of Mr. Benjamin Alfred Raworth, who for such a long period had been a member of the staff of ENGINEERING, and who for the past thirteen years had taken such a prominent position in its editorial management.

The subject of our memoir was the son of Mr. B. J. Raworth, of Sheffield, and was born at Chesterfield on June 1, 1849. He was educated at Chesterfield Grammar School and at Owens College, Manchester. Prior to going to Owens College, however, he was, from 1866 to 1867, a pupil at the works of Mr. Edward Hayes, of Stony Stratford, these works being chiefly engaged in the construction of steam launches and their engines.

After his course of studies at Owens College, Mr. Raworth proceeded to the works of Messrs. Wren and Hopkinson, Manchester, for further practical training during three years, 1867 to 1870, and while there he studied for and secured a Whitworth Exhibition of 25*l.* in 1868, and a Whitworth Scholarship of 300*l.*, this latter award being made in 1871. Subsequently, in October, 1871, he became a private assistant and draughtsman to Sir Joseph Whitworth, a position which he held for a year, when, in October, 1872, he accepted an appointment as draughtsman and assistant engineer at the works of Messrs. Siemens Brothers at Woolwich. In 1874 he left Messrs. Siemens to join his brother, the late Mr. J. S. Raworth, at Manchester in the development of some cotton-spinning machinery. During this period he took out, conjointly with his brother, two patents, one for winding yarns and the other for looms.

Late in 1880 he returned to London and joined the staff of the late Sir (then Mr.) Lloyd Wise, his position being that of chief technical assistant, and his work comprising the preparation of specifications for patents, drafting cases for the opinion of counsel, and so forth. While thus engaged he prepared the abstracts of electrical patents which were included in the late Mr. Dredge's book on "Electrical Illumination," and also the abstracts which appeared from week to week in this journal under the heading of "ENGINEERING Illustrated Patent Record." Patent specifications, as is well known, are often very complicated, and his summaries of these were remarkable for their lucidity, precision and comprehensive character. He set the model, and it is due to its maintenance that this feature of "ENGINEERING" is still so much appreciated. It was this work on patent abstracts which ultimately led to his joining the staff of ENGINEERING in 1882.

Of the services rendered to ENGINEERING in the course of the thirty-seven years during which he was so intimately associated with it, we cannot speak too highly. Occupying at first a junior position on the staff, his devotion to his work soon led to his having more important responsibilities, and on the death of Mr. Dredge in 1906 he was appointed joint editor, a position which he had thus held for thirteen years at the time of his decease. While his training was naturally identified most closely with mechanical engineering, he early recognised that it should not be purely vocational, but that a broader culture conduced to a fuller happiness. Not only did the realisation of his aim justify his uniform advice to young men to cultivate the arts as well as the sciences—the place he gave Latin in the ideal curriculum was evidence of this; but his writings always indicated that breadth of view which typifies the man of wide interests and large sympathies. Reading was one of his recreations, and he had a fine discrimination, as well as catholicity, in his choice of books and authors. These characteristics combined with an excellent literary style, sound judgment and a power of clear expression, combined to render his articles not only effective, but attractive. He was most painstaking in verifying facts, and thus his work could be implicitly relied upon. Nor was he extreme in his presentation of argument: he could see both sides of a case, and preferred to rely on a logical but calm marshalling of data to convince his reader.

In addition to his contributions to our columns, Mr. Raworth wrote a number of articles which appeared during the years 1901 to 1904, in *Traction and Transmission*, a monthly supplement to ENGINEERING. Amongst these articles, we may mention those on "The Education of Electrical Engineers"; "The Electrical Distribution of Power"; Electric Traction on Main Lines"; and "The Creative Mind"; the last named being especially characteristic of his broad views of men and things.

Of his personal traits it is difficult to write. Perhaps the one which predominated was a mental serenity even in the presence of difficulties. He was never ruffled, and was ever ready to accept suggestions. He had a keen sympathy with young engineers, and was always ready to assist them with sound advice, and to aid them in obtaining any information of which they were in want.

Mr. Raworth was elected a member of the Institution of Mechanical Engineers in 1906, of the Iron and Steel Institute in 1910, and of the Institute of Metals in 1913; but he took little part in the proceedings.

Mr. Raworth married in 1882 Florence Mary, the daughter of the late Dr. Charles Lysoe Harvey, of Southport, who predeceased him last year. He leaves one son and one daughter. His son answered the call of patriotism in 1914, and soon afterwards received a commission in the Royal Artillery. Most of his time was served in the East, first on the Salonika front, and subsequently in Egypt and Palestine. He and his sister Mrs. Moet Jones, will receive the most sincere sympathy, not only of the members of the staff amongst whom he worked so long, but also of the wide circle of engineers and other friends by whom Mr. Raworth's sterling qualities were so highly appreciated. The funeral is to take place to-day (Friday) at Brookwood Cemetery at 1 p.m.

THE SHIPPING AND MACHINERY EXHIBITION AT OLYMPIA.

In view of the unsettled state of business generally, owing to the still operating effects of the war and the unrest among Labour, the Shipping, Engineering and Machinery Exhibition, which opened at Olympia on the 25th ult., is a very creditable collection of material. The conditions under which it is held, however, have not failed to leave their mark on the exhibition, and it cannot be considered to equal some of its predecessors in technical interest. Much material of a very varied nature is shown, so that the general appeal is wide, but in no direction is it fully representative. Many of the large engineering firms, the names of which at once come to mind in considering likely exhibitors, will be found to be missing from among the stalls at Olympia, while others display one branch of their activity only. In spite of these drawbacks, however, there is much of considerable engineering interest to be seen at the show, and few engineers are likely to visit it without finding something appertaining to their work, or appealing to their interest. The synchronisation of the railway strike with the early days of the exhibition is to be regretted, as it will probably lead to fewer visitors and much less business being done than would otherwise have been the case.

Before proceeding to deal in detail with some of the exhibits, it will be well briefly to review the show as a whole, in order to give some idea of the scope of its contents. As the word "Shipping" stands first in the official title, we may first refer to such of the exhibits as may be so described. Shipping is, of course, always a difficult subject to stage in an exhibition, and many branches of the work it covers can be represented only by models. In this direction the management of the Exhibition has been able to get together a good display. Following the order of the catalogue we may mention models of H.M.S. Turquoise and various shallow-draft boats, including the famous Tigris gunboats which assisted in the capture of Bagdad, on the stand of Messrs. Yarrow and Co., Limited, of Scotstown, Glasgow; models of Clan Line steamers, shown by Messrs. Cayzer, Irvine and Co., Limited, of 2, St. Mary Axe, E.C.2; a number of models of their liners on the stall of the Royal Mail Steam Packet Company, of 18, Moorgate-street, E.C.; six ship models, by Messrs. William Denny and Bros., Limited, of Dumbarton, including the Loch Lomond, the first vessel built by the firm; models of a light cruiser, destroyers, &c., shown by Messrs. R. and W. Hawthorn, Leslie and Co., Limited, of Newcastle-on-Tyne; models of the Turbinia and of various marine turbine arrangements, by the Parsons Marine Steam Turbine Company, Limited, of Wallsend-on-Tyne; models of their ships, shown by Messrs. Elder, Dempster and Co., Limited, of Liverpool; a similar exhibit by Messrs. H. and W. Nelson, Limited, of 98, Leadenhall-street, E.C.; two good ship models by Messrs. Robert Thompson and Sons, Limited, of Sunderland; a model of the steamship Horschell, shown by Messrs. Lamport and Holt, Limited, of Liverpool; a model of the steamship Empress of France on the stand of Messrs. William Beardmore and Co., Limited, of Dalmuir; and a number of models shown by Messrs. Charles Hill and Sons, of Bristol. There are also a number of models of ships and dredgers in the section of the Exhibition devoted to Dutch firms. We may have cause later to refer to such of these as are of special engineering interest.

Ships' details lend themselves more readily to exhibition purposes than ships themselves, and among matter of this kind which is shown we may refer to an example of their well-known steam and hand steering gear on the stall of Messrs. Higginson and Co., of Hurst-street, Liverpool. Steering gears are also shown by Hydraulic Gears, Limited, of Beavor-lane, Hammersmith, who stage an example of the Hele-Shaw Martineau steering gear, and the Variable Speed Gear, Limited, of Broadway-court, Westminster, who show an application of the Williams-Janney gear to ship steering. Both these gears, which are of the hydraulic type will be familiar to readers of our columns. An electric steering gear is shown by Messrs. Lawrence, Scott and Co., Limited, of Norwich. We will refer to this again. A steam steering gear is also shown by Messrs. John Wigham and Sons, Limited, of South Hylton Engine Works, Sunderland; and a hydraulic telemotor system for the control of steering gears by Messrs. Brown Bros. and Co., Limited, of Rosebank Ironworks, Edinburgh. Ship telegraphs are staged by Messrs. Chadburn's (Ship) Telegraph Company, Limited, of Bootle, Lancashire, whose stall makes a good display. This firm also exhibit the Laval oil purifier, which we illustrated and described on page 238 *ante*. Marine governors are shown by the British Marine Engineering Company, Limited, of Basildon House, Moorgate-street, E.C., and Aspinall's Patent Governor Company, of 10, Strand-street, Liverpool. The former firm show the Ramsey governor, and the latter the well-known Aspinall governor.

Leaving shipping exhibits for the moment and attempting to give a review of the engineering exhibits of a more general nature, we find it difficult to arrange the available material into any very logical groups. If the subject of machine tools, for instance, be taken, it is found that practically the only exhibit which can properly be described as coming under that heading is that of Messrs. Haigh's (Oldham), Limited, of Globe Ironworks, Oldham, who have a large stand devoted to their products. We will later refer to some of these more in detail. There are certain tools and machine tool appliances on various stalls, but the material is not sufficient to enable us properly to deal with machine tools as a section of the Exhibition. If we turn to electrical matters we find a somewhat more comprehensive list of exhibitors, but even here there are names missing whose absence it is not always easy to understand. Of the electrical material, control gear is, perhaps, the best represented, and some of the apparatus we propose to deal with in detail. On the whole, however, the electrical exhibits are not extensive. In view of the somewhat miscellaneous nature of the Exhibition, as brought out by a consideration of these two groups, we think it will be best frankly to abandon all attempts to deal with the material in any obviously logical order, and to describe interesting apparatus or plant as it may accidentally come to our notice in visiting the Exhibition or of which we may happen to have obtained particulars. This course is forced upon us to some extent by the Railway Strike, which has delayed the receipt of particulars or drawings of some of the more important displays.

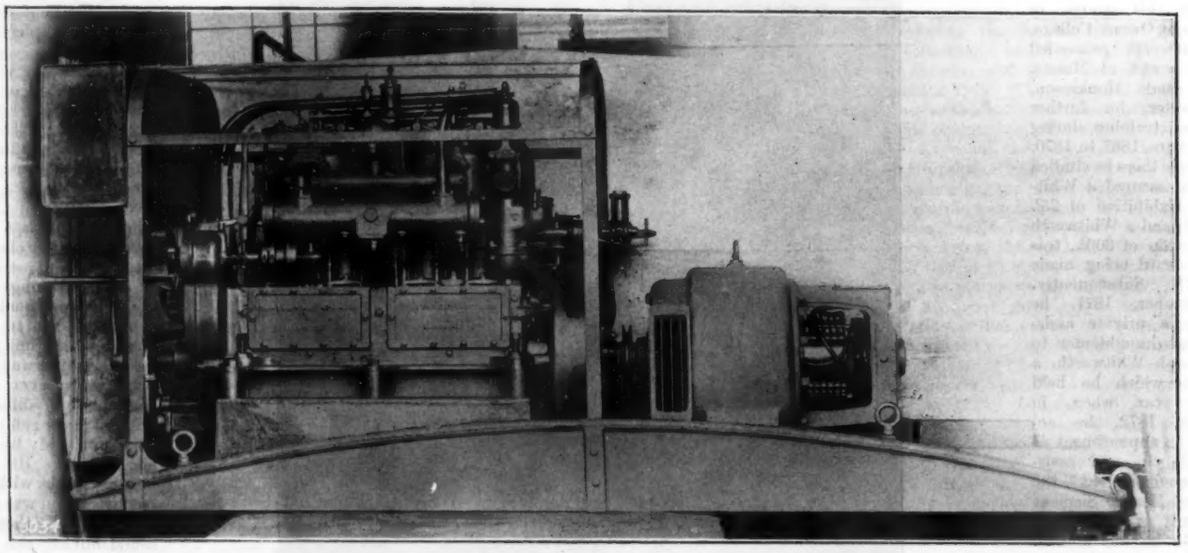


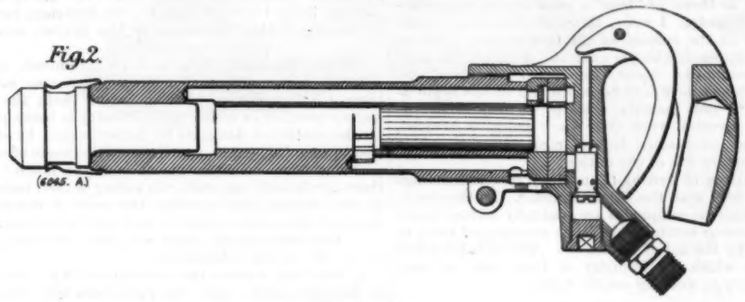
Fig. 1. Portable Electric Lighting Set; Messrs. John I. Thornycroft and Co., Limited, Southampton.

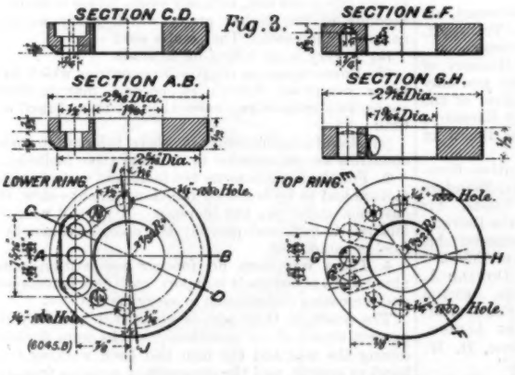
Messrs. John I. Thornycroft and Co., Limited, of Basingstoke and Southampton, are exhibiting a number of small lighting sets, of which we illustrate one in Fig. 1 annexed. This particular set is for emergency lighting purposes and consists of a four-cylinder engine of 6 in. bore and 8 in. stroke, direct-coupled to a 25-kw. dynamo, the latter being capable of an overload of 20 per cent. The normal speed of the set is 750 r.p.m. The engine is designed to run on ordinary paraffin oil, and is started either with petrol or by means of a blow-lamp which heats the vapouriser. When running, the heat of the exhaust gases is sufficient to maintain the vapouriser at the working temperature. Similar sets are built in sizes ranging from 8 kw. to 42 kw., for emergency ship-lighting purposes, and are constructed to comply with the requirements of the International Convention for Safety of Life at Sea. Messrs. Thornycroft also show a model of a double-ended, 28-ft. ship's motor lifeboat, built to the requirements of the Board of Trade. The boat, which carries 30 persons, is equipped with a Thornycroft two-cylinder motor of 15 brake horse-power, in the stern, so that the boat may be entirely controlled by one man.

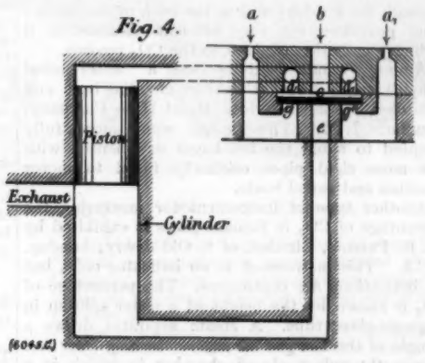
An exhibit of much interest is made by Messrs. The Clement Stevens Pneumatic Engineering Com-

pany, Limited, of 56, Victoria-street, S.W. 1. This consists of a large number of specimens of the Stevens-Hunter pneumatic hammer.

The advent of a new design of pneumatic hammer is at any time a matter of considerable interest, and in the present case the interest is heightened by the merits of the design. The Stevens-Hunter pneumatic hammer is the invention of Mr. Clement H. Stevens, C.B.E., and is the outcome of experiments carried on over a number of years, the main object of which was to produce a pneumatic hammer which, while fully capable of doing the work required of it, would reduce upkeep costs to a negligible quantity. The extreme simplicity of the hammer appears to substantiate the designer's claims in this direction. A cross-section of a Stevens-Hunter riveting hammer is given in Fig. 2. This figure so well shows the general design that it is unnecessary to refer to it in detail. We will content ourselves by dealing with the special features of the tool.







FIGS. 2 TO 4. STEVENS-HUNTER PNEUMATIC HAMMER; THE CLEMENT-STEVENS PNEUMATIC ENGINEERING COMPANY, LIMITED, LONDON.

The most novel and the chief feature of the hammer is the distributing valve. This consists of a piece of flat vanadium steel about 0·1 in. thick, working freely between two flat faces situated in two valve rings which form the handle end of the main cylinder of the hammer. These rings and the flat valve in cross-section are clearly shown in Fig. 2. It will be clear that as the distributing valve is thus situated in the wall of the cylinder it does not take up any overall length of the hammer. The advantages claimed as resulting from the use of this valve are that it cannot stick with dust and that it works perfectly without lubrication. Further, it does not lose in efficiency from long continued work, as it will be readily understood that it will always retain its airtightness by constant bedding on its seatings. It is contended that it has advantages over valves of the piston type which may be prevented from working by dust, which must be lubricated and which lose efficiency from wear.

Details of the upper and lower valve ring and of the valve are given in Fig. 3 on this page, but the operation of the valve will best be understood by reference to the diagram which is shown in Fig. 4. This diagram shows the section of the valve rings developed, and the position of the piston relatively to the valve from the outward or striking stroke and the return stroke. High-pressure air enters the top valve ring through holes a, a_1 and b; the holes a and a_1 lead by ports to the underside of the valve recess c, and the hole b to the upper side of the valve recess. Ports d and d_1 are led into the top of the cylinder from the top face of the valve recess, and port e is led from the lower face of the valve recess to the bottom or tool end of the cylinder. There is thus high-pressure air constantly on both faces of the valve.

The action of the valve is as follows: When the valve is seated on the lower face the piston is at the top or handle end of the cylinder. High-pressure air entering from b passes across the valve and up through the two holes d and d_1, and from thence to the top of the cylinder, thus driving the piston downwards on its striking stroke. In this condition the valve is unbalanced, having high-pressure air exerting pressure over the whole area of its upper surface, against a smaller upward pressure due to the combined areas of the two ports g and g_1; thus the valve is held tightly on its lower seat. When, however, the piston has moved forward sufficiently to uncover the exhaust port in the cylinder wall exhaust commences, and there is an instantaneous drop of pressure in the valve recess above the valve, and the valve changes over to the opposite face. This closes the admission of high-pressure air to the handle end of the cylinder and complete exhaust takes place at the moment that the piston strikes the tool.

When this position has been reached, the valve being seated on the upper face and the piston being against the tool, high-pressure air enters by ports a and a_1 through g and g_1, across the underside of the valve and down through the port e to the tool end of the cylinder, thus driving the piston back to the handle end. When the lower edge of the piston uncovers the exhaust there is a drop of pressure caused on the underside of the valve, which is thus forced down again on to its lower seating, and the piston and valve are again in position for the commencement of a further striking stroke. The action of the flat valve is extremely rapid, and it is claimed that a 2½-in. stroke chipping hammer will make 2,800 blows a minute.

The arrangement of the throttle valve is clearly shown in Fig. 2. It consists of a mitre-seated valve which always remains tight closed when the hammer is not working. There are no standing leakages which may occur with the piston type of throttle valve. The valve is actuated by a push rod and lever as shown. The hammer is also built with an outside actuating lever, as some users prefer that design. Chipping hammers for submarine work are also made by the company. They are fitted with a gun-metal handle having an exhaust connection from ¾-in. hose in such a position that the air and exhaust hoses can be lashed together and give perfect freedom to the diver. Should sea water get into the distributing valve it will be blown out on admitting high-pressure air and, as the valve does not require lubrication, the water cannot affect its working. In addition to hammers, of the type we illustrate, the Clement Stevens Company are also exhibiting hammer-type holders-on fitted with the Stevens-Hunter valve, plain holders-on and scaling hammers.

Messrs. George Kent, Limited, of 199, High Holborn, London, W.C. 1, show a large variety of apparatus for the measurement of water, steam and air. The various types of water meters, including Venturi meters, manufactured by this firm, are too well known to need description at this time. Their steam meter, with its automatic connections for variation in pressure of the steam, we shall deal with later. An audible water-level indicator is also exhibited by the same firm. This is especially useful to engineers who wish to know the conditions existing in reservoirs or tanks situated at considerable distances from their offices. The device usually employed consists of a warning bell or lamp operated electrically when the water reaches any predetermined high or low-level. The present apparatus utilises the ordinary telephone system. The engineer, wherever he may be on the telephone system, calls up a number allotted to his reservoir, and when the connection is made his receiver tells him exactly what the level is at that moment. His information arrives in the form of audible clicks, sounded in groups of threes, with a longer pause between the digits of the number being sent. The standard instruments give 100 different readings over the whole range of level, but twice this number can be provided for if desired. There is no difficulty in interpreting the meaning of the sounds heard, and the instrument repeats the information thrice in succession to avoid uncertainty. It then "rings off" and is ready to be called up again. The mechanism is extremely simple and unlikely to get out of order, and if desired a phonographic transmitter is supplied which will give the information verbally. Should the water level rise or fall to a dangerous level, the apparatus will call up the engineer automatically, through the telephone exchange.

Messrs. George Kent, Limited, exhibit also the "Clear view screen," which enables a perfect view to be obtained whether spray, rain or snow is beating upon the window. It consists of a disc of glass kept in rapid rotation by means of a tiny electric motor. The rotation causes all water or snow to be instantly thrown off, and a clear view to be obtained whatever the weather conditions. The disc is about 11 in. in diameter, and for naval work it is mounted in a rotatable hood which protects the head and shoulders of the observer from the weather and enables him to use binoculars with comfort. A Pelorus or dummy compass is provided inside the hood for taking bearings. So efficient is the rotating disc in clearing itself, that even if drenched

with a bucketful of water, perfect definition with an eight-power pair of binoculars is restored in 2 seconds. The clear-view screen has been largely adopted in the Navy and the merchant service, and is being also applied to aeroplanes, motor cars, locomotives, &c. For such purposes the disc is simply mounted in the ordinary wind shield or window.

The Auto Recorder Company, Kent-street Works, Leicester, exhibit their CO_2 recorder for boiler plants, which, however, was fully described in these columns some years ago.* It is noticeable for its mechanical construction and its departure from the lines of the laboratory type of apparatus which has earned a certain amount of unpopularity in boiler rooms. The instrument exhibited can be taken apart for cleaning and reassembled in working order by anyone exercising ordinary care, which is a very commendable feature. The same company show the "Midland" self-contained boiler furnace, which can be readily fitted to any Lancashire boiler without structural alterations. It comprises a closed ashpit with controllable air supply, both through the fire-bars and at the back of the bridge, thus providing for very efficient combustion if ordinary attention is given to the CO_2 records.

Among minor exhibits are a water-cooled exhaust pipe, made of flexible metallic hose and exhibited by the Interlock Metal Hose Company, London, N.22. The design was successfully adopted to avoid the breakages experienced with the more rigid pipes originally fitted to motor launches and patrol boats.

Another type of instrument for measuring the percentage of CO_2 in furnace gases is exhibited by W. R. Patents, Limited, of 8, Old Jewry, London, E.C.2. This instrument is an indicator only, but its indications are continuous. The percentage of CO_2 is shown by the height of a water column in a gauge-glass tube. A steam aspirator draws a sample of the flue gas through a cleaning filter and thence through a closed chamber in which is a sealed porous pot. Inside the pot is a cartridge of solid caustic potash which absorbs the CO_2 from the gas which finds its way through the walls of the pot. The consequence is that the pressure inside the pot is always lower than in the chamber by an amount proportional to the CO_2 in the gas, and this difference of pressure causes a water column to rise in a graduated leg of a U-tube and thus to serve as an indicator. The instrument contains no moving parts at all and is exceedingly simple. Provided that the filter cleans the gas properly so that the porous pot retains its condition, the indications should be reliable. It is guaranteed to have an accuracy within 1 per cent., and to respond quickly to variations in the composition of the furnace gases. The aspirator is said not to require more than 1¼ lb. of steam per hour.

Messrs. Kelvin, Bottomley and Baird, Limited, of 18, Cambridge-street, Glasgow, exhibit principally their Pneumercator† tank gauges and ships' draught indicators. The tank gauges are designed for showing the quantity of liquid in tanks and are particularly useful in connection with measurements of oil and liquid fuel in steamers. There is no possible comparison between the convenience of the pneumercator method and the alternative of gauging by means of a rod. The apparatus, as is generally known, consists of a kind of diving bell of a few inches diameter, fastened at the bottom of the tank. The compression of the air in the diving bell due to the head of liquid is transmitted by means of a small copper pipe to a suitably calibrated gauge which may be situated at a considerable distance from the tanks. The special point about the apparatus is the means afforded to ensure accuracy by restoring a true zero reading before making an observation. This is done by blowing out the diving bell with air, furnished either by a hand pump or a small compressor. It should be noted that the pneumercator measures the true weight of liquid in the tank, and has the advantage over any volumetric method in that changes of specific gravity due to temperature do not affect its accuracy. The draught indicator works on exactly the principle we have described. It gives readings of draught both fore and aft, and from the mean draught the tonnage displacement can be read from a scale on the instrument.

(To be continued.)

* See Engineering, vol. lxxxv, page 785.
† See Engineering, vol. civ, page 120.

INDUSTRIAL NOTES.

We deal in our leader, on page 449, with the railway crisis, a few notes concerning which we published on page 407 *ante*. The situation was reviewed by former articles and notes, on page 409 of our issue of March 28, and on pages 441 and 445 of our issue of April 4. The railwaymen went out on strike last Friday at midnight.

Last Wednesday a deputation of the railwaymen's and other unions waited on the Prime Minister, who stated: "If I am asked to see the Executive of the National Union of Railwaymen, my answer is that I shall be ready to meet them and hear what they have to say, but you will, I am sure, agree with me that there is nothing to be gained by any ambiguity, more especially as there has been a good deal of misunderstanding already. I want, therefore, to make it quite clear that in the opinion of the Government it would be quite impracticable to continue negotiations until work is resumed. Apart from other considerations, the Ministers who would be concerned in the negotiations could not possibly attempt to deal with the questions involved while their whole energy is devoted, as it must necessarily be, to improvising means of carrying on the life of the nation."

At the time of writing (Thursday), further meetings are being held with the Prime Minister. In the meantime the various companies are gradually adding trains to the skeleton service which they commenced early in the week by the aid of volunteers. The distribution of foodstuffs which the Ministry of Food took in hand immediately is working satisfactorily.

The Railway Executive Committee addressed, on September 23, to Sir Eric Geddes, Minister of Transport, the following letter tendering their resignation:—

"In view of the inauguration of the Ministry of Transport as from to-day it is probable that you may wish to reorganise the method of the control of the railways, hitherto exercised by the Railway Executive Committee through the authority of the Board of Trade under the Act of 1871.

"The members of the Railway Executive Committee, whose signatures appear hereunder, therefore beg to place their resignation in your hands. Sir Robert Turnbull, the remaining member of the Railway Executive Committee, has already tendered his resignation, to the President of the Board of Trade.

"(Signed) H. A. Walker, Sam Fay, Donald A. Matheson, William Forbes, Arthur Watson, Charles Dent, Francis H. Dent, F. Tatlow, Charles Aldington, A. Kaye Butterworth, H. W. Thornton, I. T. Williams."

In his reply, addressed to Sir Herbert Walker, Sir Eric Geddes said that in receiving the resignations he was happy to be able to recall the very cordial expressions of goodwill which the committee extended to him, and the committee's assurance that he (Sir Eric) could look for their continued support and assistance in the task with which he was charged. That assurance, he added, was entirely in keeping with the traditions of the railway companies and of the Railway Executive Committee.

Writing to Sir Herbert Walker from the Board of Trade, Sir Auckland Geddes states: "Now that the control of railways has passed from the Board of Trade to the Minister of Transport, I should like to take an opportunity of expressing my high appreciation of the work of the Railway Executive Committee, and more particularly of yourself. I have had to depend upon you and the committee for assistance in many very difficult matters, and I can certainly say that you have never failed me, and I shall always look back with pleasure upon my association with you and your colleagues in railway matters. I am sure that in times to come the Government may rely upon receiving the same whole-hearted assistance they have received in the somewhat difficult period that we have passed through together."

The strike of iron moulders dealt with in our last issue still continues. Speaking on this point on September 25, in connection with the Shipping, Engineering and Machinery Exhibition at Olympia, Lord Weir stated that "the iron-moulders are on strike because they are selfish enough to demand priority of consideration for their wages question before those of other trade unions, notwithstanding that they had been parties with these trade unions to an agreement determining a date when their claim would be heard. True, they have seceded from that agreement, but a tactical movement cannot hide the character of their action. These are facts, but I wish to point out that this very society, whose members want more wages, have absolutely declined over many years to allow other members to accept legitimate systems of payment by results, and thereby afford them the opportunity to increase their earnings. They decline to allow freedom to any one except a moulder trained for seven years to work a moulding machine, which can be learned in a few days by almost any one. They decline to allow freedom to any one but a skilled man to make cores, a large proportion of which can be made by a girl or a limbless soldier after a few days' training, even although the employer is willing to pay the skilled man's rate. There has been less progress in the ordinary iron foundry in this country in the last twenty years than in any other class of engineering, due to the influence of restrictive customs. These restrictive customs prevent extension and enterprise on the part of the employers in a department of industry on which all classes of engineering are directly dependent. To-day the labour cost of certain castings in Great Britain is double that of corresponding castings in the United States, and the American moulder is earning double the wages of the British moulder.

Messrs. Marshall, Sons and Co., Limited, Gainsborough, have addressed a circular letter to each of their 4,500 workmen, putting before them the very serious position in which their industry is being placed by the continued demands for higher wages, by strikes and threatened strikes, and the resulting state of unrest and slackness. If these are to continue much longer there can be only one end—the killing of their industry. In their letter, they contrast the position during the war with the present position and add the following:—

1. The Government then was the customer, now the public are the customers.

2. For vital reasons the Government was compelled to buy the goods—now, the public are not compelled to buy the goods and, in many cases, refuse to do so on account of the higher prices which every advance naturally increases. The results are:—

(*a*) A very large falling-off in trade.

(*b*) Encouragement is given to countries which have never competed before, to become manufacturing countries; to give two cases they mention Brazil and Chili.

(*c*) Manufacturers only in their infancy in other countries are encouraged to increase their facilities.

3. For the same reasons the increased cost of manufacture had to be borne by the Government—now, the customer must pay the increase. If he will not, the business is lost, and possibly the order is taken by a foreign competitor.

4. There was then no foreign competition—now, nine-tenths of our trade is export, and there is strenuous and increasing competition in every market.

The position, they add, is made still worse by the present strike of the moulders; stocks were depleted during the war and the firm had been working from hand to mouth, and the stoppage of supplies from the foundry must very soon automatically close most of the other departments of the works. Messrs. Marshall have already given notice of suspension to a number of their employees, which is a direct result of the strike. The pity of the matter is that the bulk of the moulders would have preferred to have remained at their work and await the result of next month's conference on the position of the engineering industry as a whole.

The latest financial report issued by the Amalgamated Society of Engineers, states that the funds of the organisation now amount to over 2,750,000*l.*, in round figures. At the end of June there was 1,918,471*l.* in the general fund and 857,380*l.* in the superannuation reserve fund. The half-year's increase was 142,895*l.*, as compared with 213,762*l.* in the second half of 1918. Arrears are up from 58,885*l.* to 75,368*l.* A balance of 4,753*l.* stands to the credit of the political fund. The membership, which was 312,762 on June 30, is now 313,727.

Spanish Mining and Industrial Directory.—The annual directory of mines, metallurgy, electricity, &c., in Spain, "Anuario de Mineria, Metalúrgia, Electricidad y demás Industrias de España," published by the "Revista Minera, Metalúrgia y de Ingenieria," Madrid, has now appeared; its price is 8·50 pesetas. The directory contains a list of all the mines classified according to the metal and province; the mining, metallurgical, electrical and chemical societies established in Spain, with their capital, address and administrative boards, and the metallurgical and chemical factories, and all the Spanish civil engineers, their addresses, and the railway companies of general and mining interest. Fees of the Laboratory of the School of Mines for examining and analysing ore are quoted. Official laws and arrangements referring to the metallurgical and mining industry, &c., are given.

THE SQUEEGEE ROTARY PUMP.

CONSTRUCTED BY THE AVAMORE ENGINEERING COMPANY, LIMITED, LONDON.

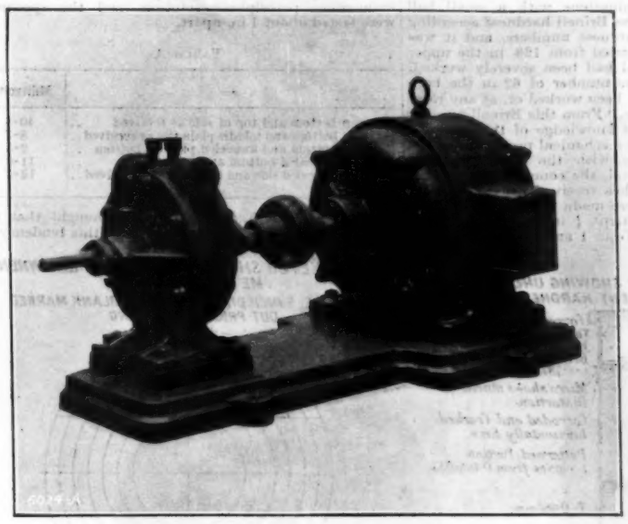


FIG. 1. 1¼-IN. PUMP DIRECT COUPLED TO MOTOR.

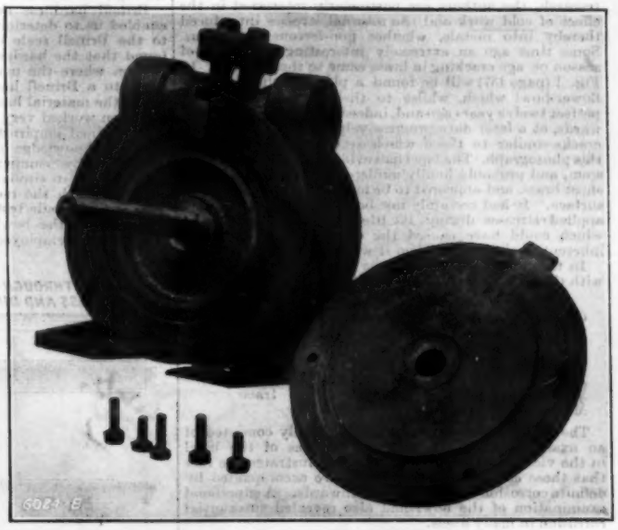
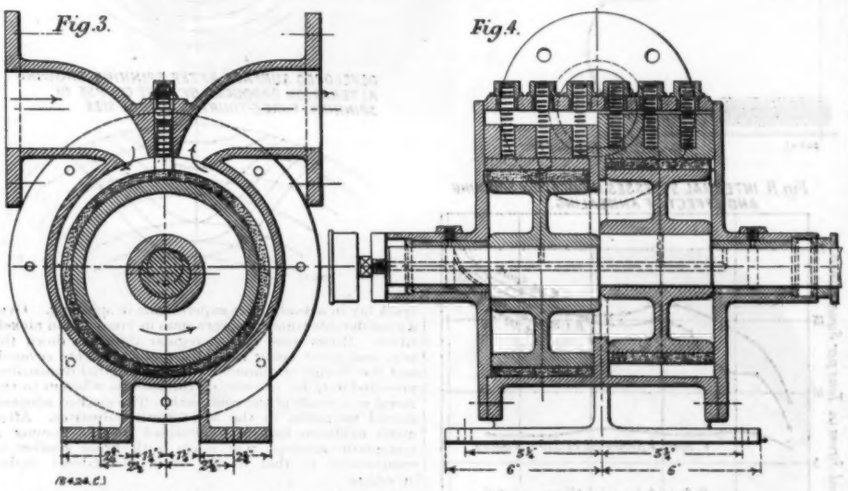


FIG. 2. 1½-IN. PUMP WITH COVER REMOVED.



ON the present page we illustrate a new design of rotary pump which has been recently placed on the market by the Avamore Engineering Company, Limited, of Queen Victoria-street, London. The pump has been named by the makers the "Squeegee"; it is of the positive type, and is made at present in six standard sizes.

The leading features of the pump are simplicity of design, high speed and, due to the fact that the rotor has a rolling motion imparted to it by the casing, the wear is reduced to a minimum. It is suitable for pumping gritty or muddy water and, by using all metal rotors, oil.

In Fig. 1 the pump is shown direct-connected through a flexible coupling to an electric motor, whilst Fig. 2 shows the pump with one of the covers removed; the rotor, which is encircled with a band of indiarubber, is clearly seen. Fig. 1 illustrates the 1¼-in. pump, which at 1,000 r.p.m. has a capacity of 1,000 gallons per hour when working against a total head of 100 ft., under which condition it takes about ¾ h.p.; whilst the pump shown in Fig. 2 is the 1½-in. size, it has at 1,000 r.p.m. a capacity of 2,000 gallons per hour when working against a total head of 100 ft., and takes about 1½ h.p.

The leading particulars of the design are shown in Figs. 3 and 4. The pump consists of six main parts—the casing, two covers, shaft and the two rotors, which in the standard design are covered with indiarubber. The casing and rotor discs are generally made of cast-iron, but there is no reason why these should not be made of Admiralty bronze or a special metal; the shaft is made of steel and is carried in two bearings; the eccentrics, which are solid with the shaft and have only a small throw, impart movement to the rotors, which are a loose fit on the eccentrics.

On referring to Fig. 3 it will be seen that the displacement is caused by the rolling of the rotors when driven round by the eccentric on the main shaft. When the shaft is rotating in an anti-clockwise direction (see the arrows on the drawing, Fig. 3) the rotor rolls round in the same direction, but on account of its being smaller in circumference than the track in the casing, it rotates in a clockwise direction, but only in proportion to the difference between the circumference of the casing or track and that of the rotor. The point of contact between the rotor and casing is constantly rolling forward in an anti-clockwise direction. It will readily be seen that the shaft may be driven from either end and in either direction, and for this reason the inlet and outlet connections are interchangeable and therefore are not specially marked.

Small deflecting valves, one for each rotor, are placed in the upper portion of the casing, and are kept in position and up to their work on the rotor by the small springs shown in Figs. 3 and 4.

We have had an opportunity of seeing one of the pumps at work and of examining the parts of another pump which had been at work for over six months. The pump ran very smoothly and quietly, and the delivery of water was continuous and without apparent pulsation. When this pump was run on a closed circuit at 1000 revolutions per minute, the vacuum gauge, fitted on the suction side, stood at 29 in., and when the rotor was turned by hand at about 60 revolutions per minute the gauge indicated 25 in. of vacuum. Priming of the pump is unnecessary. The wear on the pump which had been in service for some months was very small.

We understand that the company are prepared to make pumps of this type outside their standard sizes, of which, as previously mentioned, they have six. The standard range is from 1 in. to 4 in. diameter of pipe connections, with a capacity of from 700 gallons to 13,000 gallons per hour when run at 1,250 r.p.m. and 720 r.p.m. respectively, but any of the pumps may be run at any speed up to the maximum and will deliver a proportional quantity of the liquid, being pumped against any head within the limit of 100 ft. for the smaller sizes and 150 ft. for the larger.

DIESEL ENGINE USERS' ASSOCIATION.—At the next meeting of the Diesel Engine Users' Association the subject of the life of connecting-rod belts and their periodical renewal, as well as the general question of heat treatment, is to be further discussed. Information is also to be given as to the proposed Research Association under the Government scheme for the purpose of carrying out research work on liquid fuels for use in Diesel and semi-Diesel engines.

HEIGHT OF GAS CAP IN SAFETY LAMPS.—The height of the blue cap, which appears over the flame of a safety lamp in explosive gases, increases with the proportion of methane and with the temperature of the flame. The latter depends upon the lamp fuel used. Davy used oil, Wolf benzene, Pichler alcohol, Clowes hydrogen. Exact measurements of the flame temperature have hardly been made, and C. M. Young, of the University of Illinois, did not aim at very accurate temperature determinations either in the experiments which he describes in the August Bulletin of the American Institute of Mining Engineers. But he observed the change in the height of the cap with different percentages of methane (or its equivalent) in the gas burnt in a Clanny safety lamp (the bonnet of which was removed), and with different temperatures of a wire coil heated by an electric current, to temperatures measured with fair reliability. The coil was made of platinum wire, 0·016 in. in diameter, wound to a coil of eight turns, ¼ in. long, ⅛ in. on outside diameter. A thermocouple was placed in the coil. The city gas used was "approximately equivalent in cap-forming power to air-methane mixtures containing 1 per cent., 2 per cent., 3 per cent. and 4 per cent. of methane." Plotting the height of cap as ordinate against the temperature as abscisse he obtained fairly regular curves, keeping nearly horizontal up to about 800 deg. C., and then curving upward. The striking feature is that even in the 4 per cent. mixture he never observed a cap at 680 deg., but a cap of about ⅛ in. in height appeared suddenly as soon as the temperature rose to 662 deg. One might expect that the cap would gradually become distorted while increasing in height. High caps of 1·5 in. were difficult to measure, because they fluctuated and their points were indistinct. With 2 per cent. of methane the cap was hard to see. The 1 per cent. mixture showed a faint cap of ⅛ in. when the coil was at dark red glow; at higher temperatures the glow of the coil overpowered the cap.

SEASON CRACKING.*

By Dr. W. H. Hatfield, Member (Brown-Firth Research Laboratories, Sheffield), and Captain G. L. Thirkell, A.E., A.I.F., B.Sc. (Tasmania).

Like other investigators engaged in metallurgical research, the authors are particularly interested in the effect of cold work and the internal stresses introduced thereby into metals, whether non-ferrous or ferrous. Some time ago an extremely interesting specimen of season or age cracking in brass came to their notice. In Fig. 1 (page 457) will be found a photograph of a brass flower-bowl which, whilst to their certain knowledge perfect twelve years ago and, indeed, for some years afterwards, at a later date progressively developed numerous cracks similar to those which were easily observable in this photograph. The bowl had evidently been drawn out, spun, and probably finally malleted from a disc of rolled sheet brass, and appeared to be lacquered on the external surface. It had certainly not been called upon to resist applied stresses during its lifetime, and any stresses which could have caused the cracks must have been inherent in the article when it was first put into service.

In the first place, an analysis was made of the brass, with the following results :—

	Per Cent.		Per Cent.
Copper	... 63·93	Bismuth	... less than 0·005
Zinc	... 35·92	Cadmium	... less than 0·005
Lead	... 0·363	Nickel	... nil
Tin	... 0·033	Antimony	... nil
Iron	... 0·113	Arsenic	... trace
Aluminium	nil	Sulphur	... trace
Manganese	nil		

The earliest micro-examination naturally consisted of an examination of the external surfaces of the bowl in the vicinity of a crack, and Fig. 2 illustrates the fact that these cracks were here and there accompanied by definite corrosion from the surface inwards. A superficial examination of the bowl had also revealed substantial corrosion in many areas.

The microstructure of the bowl was examined sectionally and on the surface, and interesting data were obtained. The bottom of the bowl, where little work, except perhaps a preliminary rolling, had been done upon the material, had a structure as shown in Fig. 3, which will no doubt be considered typical of this class of material, whilst towards the top of the bowl, in some of the severely worked areas, the structure was as typified in Fig. 4.

In Fig. A will be found a rough section, through the length of the bowl, which gives some idea of the varying amounts of work which the brass had received. Figs. 5 and 6 are of interest as being taken from the face of the bowl, *i.e.*, being the surface immediately under the lacquer. Fig. 5 gives some idea of the work which has been put upon the material, and one crystal, marked with a star, can actually be seen in the process of breaking down. It will be seen that we have here the definite breaking down of the crystal without any separation of crystal surfaces. In other words, under these particular conditions of stress and strain the crystal has proved less capable of accommodating itself to the work which has been put upon it than would have been anticipated, since there is no evidence, if the photomicrograph is studied, of any rupture along the crystal boundaries. Whilst studying this particular crystal, it is of interest to compare Fig. 12. One crystal is there marked X, and it will be seen how corrosion, extending from a crack, is eating into the area of the crystal, which has been damaged during plastic deformation. It would appear that the crystal starred in Fig. 5 contains, in the interstices between the fractured portions, a material which is more susceptible to attack than the crystal proper. Whilst on this particular aspect of the matter, it is of interest to study also Fig. 13, particularly the crystal marked A, where it will be seen that the crack actually commenced to enter that particular crystal and ceased to propagate, probably owing to the fact that its "energy" was subdivided in the formation of four or five minor cracks, and yet there seems to be evidence that in that case the crack runs through the corner of the crystal. These observations are recorded to emphasise the deduction which the authors have drawn to the effect that whilst essentially the cracks are between the crystals, the material seems to be capable of being almost as easily ruptured through the crystals as round them. Fig. 7 illustrates the general sectional structure at right angles to the length of the bowl, whilst Fig. 8 shows a section through an actual (vertical) crack. Fig. 9 shows, at 500 magnifications, the structure of the crack portrayed in Fig. 8, and it is particularly interesting in that it confirms the fracturing of brass between the crystal boundaries, although, as before pointed out, there can be seen obvious exceptions which will certainly be found of interest when theoretical considerations are being discussed. Figs. 10 and 11 illustrate the ruptures at right angles to the main crack and again largely show the intercrystalline fracture. Fig. 13 is of particular interest. It is a clear photomicrograph at 500 diameters showing the tearing away of one crystal from another, but, curiously, actually shows the tear or cracks running into one of the crystals, showing therefore, as just mentioned, that there is probably little difference between the cracks running between and through the crystals. Fig. 14 shows a vertical crack merging into the polished face, and it will be seen how the crystals, in this instance, are separating from each other.

So far the authors have placed before the members a photograph of the article under examination, the analysis of the material from which it was made, and also, from a micrographic standpoint, the structure of the material, together with the position of the cracks in relation to the structure. In all cases the cracks appear to start on the exterior, generally in or running through seats of corrosion, and extend inwards, usually running round the crystals, but at other times running into and sometimes through the crystals.

Brinell hardness determinations with a small ball enabled us to determine the Brinell hardness according to the Brinell scale of hardness numbers, and it was found that the hardness varied from 128 in the upper portion where the material had been severely worked, down to a Brinell hardness number of 62 in the base where the material had not been worked or, at any rate, had been worked very little. From this Brinell number one obtained empirically a knowledge of the hardness and some knowledge of the mechanical properties of the material. By comparisons with the work of other investigators in similar metal, the comparative amount of work which the metal has received can be thereby surmised. Tensile tests were made upon material from the walls of the bowl. Strips ½ in. wide with 1 in. parallel were employed. Tests 1 and 2, taken circumferentially, gave M.S. in tons per square inch 23·6 and 23·3. Test 3, one piece taken vertically, gave 22·1 tons per square inch.

Fig. A.
SECTION THROUGH POT SHOWING UNEVEN THICKNESS AND DIFFERENT HARDNESS.

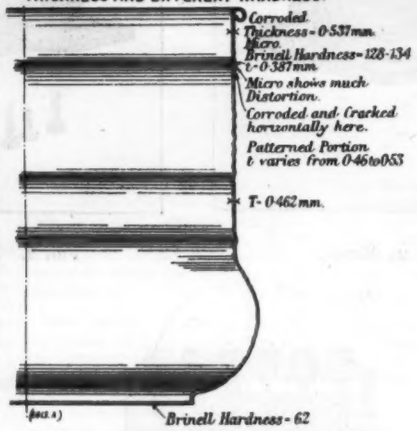
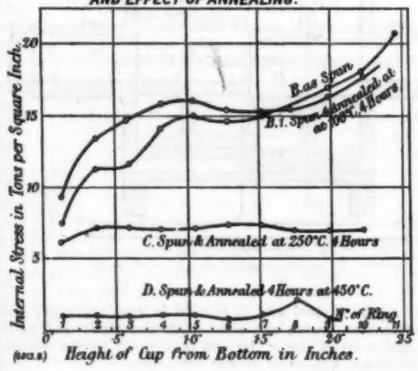

Corroded.
Thickness - 0·537 mm.
Micro. Brinell Hardness - 128-134
t - 0·387 mm.
Micro shows much Distortion.
Corroded and Cracked horizontally here.
Patterned Portion. t varies from 0·46 to 0·53
T - 0·462 mm.
Brinell Hardness - 62

Fig. B. INTERNAL STRESSES INDUCED BY SPINNING AND EFFECT OF ANNEALING.



		In. high.
A.	Failed in mercurous nitrate ..	2·33
B.	" " " ..	2·55
C.	" " " ..	2·33
D.	" " " ..	2·33
E.	Annealed at 600 deg. C. No stress	2·33
F.	Did not fail in mercurous nitrate	2·33
B1.	" " "	2·33

Subsequently test-pieces were cut from the sides of the bowl and annealed at different temperatures. In their original state they would not bend more than 90 deg. before cracking, but after annealing at 450 deg. C. for 4 hours were much softer and less brittle. The microstructure after such treatment is given in Fig. 15. Microscopic examination showed that the metal had partly recrystallised. Specimens annealed at 550 deg. C. for 1 hour became quite soft and ductile, and apparently had, by that treatment, lost all their previous brittleness. The metal had quite recrystallised, and the grain size was larger than that portrayed in the photomicrograph, Fig. 15.

Etching Reagents, &c.—For etching purposes 10 per cent. chromic acid in water with hydrogen peroxide, which was added at the time of etching until the solution turned brown and effervesced. It was found that the specimen had to be kept moving to avoid gas bubbles.

A 10 per cent. ammonium persulphate solution has also been used with good results.

With regard to the mercurous nitrate solution used in testing the spun rings, the following composition was employed :—65 grammes of $HgNO_3$, 15 c.c. of nitric acid, diluted with 900 c.c. of water.

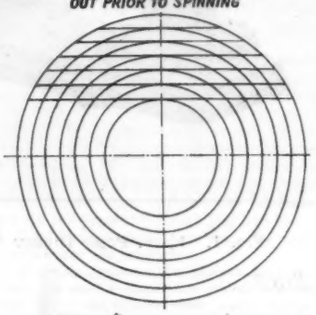
It is interesting at this stage to introduce a little evidence obtained from experiments made to determine the difference in potential between the metal in the different parts. The electrolyte was 10 per cent. ammonium persulphate solution, and the specimens were tested about 1 in. apart.

Table A.

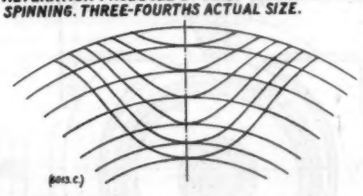
—	Millivolts.
Between bottom and top of side as received ..	10·8
Between bottom and middle plain rim as received ..	8·7
Between bottom and annealed piece of bottom ..	2·5
Between annealed bottom and top of side	11·0
Between annealed side and top of side as received ..	12·2

Experiments in Spinning.—It was thought that the most obvious way to find a solution of this tendency to crack lay in actual direct experiments in spinning. Over a considerable time cups were spun in brass and in nickel-silver. Rings were cut at regular intervals down the cup, and after being carefully measured were severed, and the change of diameter over the original dimensions provided data for calculating the stresses inherent in the metal as a result of the cold work. The method adopted should be useful in the non-ferrous industries. After much evidence had been obtained in this manner a systematic attempt was made with brass similar in composition to that in the brass flower-bowl under investigation.

Fig. C. SKETCH SHOWING WHAT HAPPENS WHEN METAL IS SPUN.
N°12 GAUGE. 5-INCH DIAMETER BRASS BLANK MARKED OUT PRIOR TO SPINNING



DEVELOPED SURFACE AFTER SPINNING SHOWING ALTERATION PRODUCED BY FIRST COURSE OF SPINNING. THREE-FOURTHS ACTUAL SIZE.



In considering these results as much information as possible should be placed before the members, and Fig. 17, page 460, is useful in this connection. A shows the first stage of spinning from the blank, after which the cups were annealed at 650 deg. C. for 5 minutes and then spun again to the shape shown in B. They were now again annealed at 650 deg. C for 5 minutes and finally spun to the finished shape C. In the upper portion of this figure will be seen reproduced examples of the rings as cut from the cup and also after severing, giving an actual idea as to the extent to which these rings opened out.

Seven cups were made from the same sheet of brass of gauge 12 in. thickness. The same amount and quality of work was put on to each cup under practically identical conditions. As regards size, the cups were 2·33 in. high by 2·33 in. diameter at the top. Unfortunately, cup B, given below, was one ring higher than the others, making it 2·55 in., but the conditions of spinning and annealing were exactly the same for all. They were all measured up. Cup A was placed in $HgNO_3$, and (*a*), Fig. 16, page 460, shows the interesting manner in which it split after 7 minutes' immersion, whilst (*b*), Fig. 16, shows the original shape of the cup prior to immersing in the $HgNO_3$. Cup B was cut into rings and the stresses were calculated (see Appendix I). Cup B1 was annealed for 4 hours at 100 deg. C., cut into rings, and the stresses calculated. Cup C was annealed for 4 hours at 250 deg. C., measured, cut into rings, and the stresses calculated, Cup D was annealed for 4 hours at 450 deg. C., cut into rings, and the stresses calculated. Cup E was annealed for 4 hours at 600 deg. C., cut into rings, and the stresses measured. Cup F, after annealing for 4 hours at 450 deg. C., was put into $HgNO_3$ for 24 hours and did not crack; the actual cup (*b*) shown in Fig. 16 illustratesthis cup after immersion in the $HgNO_3$.

This work was put through with reasonable accuracy,

* Paper read before the Institute of Metals, September 24, 1919.

FIG. 1.—The brass plant bowl which formed the subject of the investigation.

FIG. 2.—Shewing cracks on polished surface of bowl. × 500. Unetched.

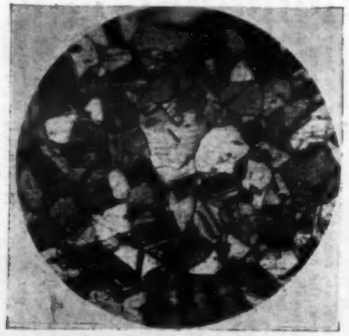


FIG. 3.—Microstructure of bottom of bowl as received. × 100. Etched.

FIG. 4.—Micro. of heavily worked upper portion. × 100. Etched.

FIG. 5.—Face of bowl. × 100. Etched.

FIG. 6.—Face of bowl shewing vertical crack. × 100. Etched.

FIGS. 1, 3-4 reduced by one-fourth. FIG. 2 reduced by one-third.

FIG. 7.—A Typical cross section. × 100. Etched. Reduced by one-fifth.

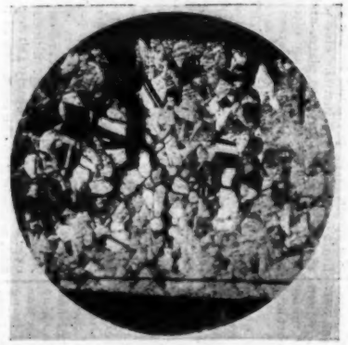


FIG. 8.—Cross section of vertical crack. × 100. Etched. Reduced by one-fifth.

FIG. 9.—Cross section of vertical crack, same as Fig. 8. × 500. Etched. Reduced by one-third.

and the results are of considerable interest. (See Table B.)

Table B.—*Brass.*

—	d_1.	d_2.	w.	t.	Tons per Sq. In.
		B. *As Spun.*			
1	2·125	2·225	0·4	0·037	7·4
2	2·14	2·39	0·77	0·0315	11·2
3	2·15	2·41	0·83	0·035	11·5
4	2·16	2·54	1·19	0·027	14·0
5	2·19	2·62	1·34	0·027	15·0
6	2·20	2·60	1·25	0·028	14·60
7	2·22	2·63	1·29	0·0285	15·0
8	—	—	—	—	—
9	2·26	2·674	1·30	0·033	16·9
10	2·27	2·64	1·15	0·039	18·0
11	2·28	2·60	1·00	0·051	20·6
		B1. *Annealed 4 Hours at 100 Deg. C.*			
1	2·11	2·28	0·53	0·035	9·2
2	2·13	2·42	0·98	0·031	13·3
3	2·15	2·56	1·29	0·026	14·6
4	2·16	2·64	1·49	0·025	14·7
5	2·17	2·66	1·52	0·0255	15·9
6	2·19	2·65	1·43	0·026	15·2
7	2·21	2·65	1·39	0·027	15·2
8	2·23	2·66	1·34	0·0285	15·4
9	2·275	2·67	1·25	0·033	16·2
10	2·31	2·69	1·2	0·038	17·6
		C. *Annealed 4 Hours at 250 Deg. C.*			
1	2·12	2·22	0·32	0·37	6·0
2	2·13	2·27	0·45	0·0315	7·0
3	2·15	2·32	0·53	0·028	7·10
4	2·16	2·34	0·56	0·027	7·00
5	2·18	2·365	0·58	0·0265	7·10
6	2·20	2·39	0·6	0·027	7·35
7	2·21	2·40	0·58	0·028	7·3
8	2·23	2·395	0·52	0·03	6·95
9	2·275	2·42	0·46	0·034	6·85
10	2·31	2·425	0·36	0·0435	6·96
		D. *Annealed 4 Hours at 450 Deg. C.*			
1	2·13	2·15	0·05	0·034	0·89
2	2·13	2·15	0·06	0·028	0·88
3	2·14	2·16	0·06	0·0275	0·85
4	2·15	2·17	0·07	0·0275	0·99
5	2·16	2·18	0·07	0·028	0·99
6	2·18	2·20	0·05	0·029	0·72
7	2·19	2·21	0·07	0·0285	1·0
8	2·21	2·26	0·15	0·03	2·10
9	2·240	2·25	0·04	0·0395	0·75

The rings from the cup annealed at 600 deg. C. are not included, as it was found that the stresses had been entirely dissipated.

The stresses in the different cups as affected by the different treatments are indicated in Fig. B (page 456).

During the spinning experiments it was found that when the material was overworked without annealing, as would be expected, cracks were produced, and it was considered necessary to determine whether, in such instances, the cracks also were essentially between the crystals. Fig. 18 (page 459), at 100 diameters, etched, illustrates the structure on the face of one brass experimental cup, and also shows a surface crack which runs for the most part between the crystal boundaries. The internal stress in this instance was approximately 20 tons per square inch. Fig. 19 (page 460), which is at 500 diameters, gives a more perfect view of a mercurous nitrate crack. The experiments showed that cracks induced by mercurous nitrate were also mainly between the crystals.

The work which the authors have in hand is by no means completed, but it was thought that sufficient evidence had been secured to present to the Institute.

Before leaving the experimental work, however, they would like to record the very interesting fact that malleting after spinning, whether practised in brass or in nickel-silver, results in an apparent lowering of such stresses produced in spinning, comparative values of the amount of "spring" (see Appendix I) of comparative examples being in the ratio 16 : 10 in favour of the subsequent malleting, although local high stresses may result. Incidentally the curves produced by plotting the stress in tons per square inch against the position in the cup in inches clearly bring out the effect of critical amounts of work on lines similar to those indicated in several recent papers. The work in this direction, however, must be deferred to a later communication. Fig. C will be helpful in assisting the members to visualise the nature and the amount of deformation which the sheet has received as a result of the process of spinning into the first stage A (Fig. 17) of the standard experimental cup employed in the investigations.

Discussion of the Results.—During the investigation reference has been made to many excellent researches dealing with the effect of cold work on non-ferrous and ferrous materials, and the bibliography of the works consulted will be found at the end of the paper (Appendix II). It is impossible in the space at our disposal to deal adequately with the work of previous investigators, but the authors feel that their views quite coincide with Dr. Desch's when he points out* that the stress in a thin outer layer of cold-worked material may reach very high values, approaching the breaking stress of the material, and that a slight scratch may suffice to start a crack. Dr. Desch's further suggestion that superficial corrosion, by relieving the stress locally, often causes season cracking, is entirely in line with the conclusions formed by the authors. In the course of their inquiries they read with much pleasure a paper by Mr. J. T. Milton,† and as regards the conclusions therein stated the authors are in general agreement, except that as regards conclusion 4, where it is stated that failures occur where stresses are over 5,000 lb. to 6,000 lb. per square inch; the authors suggest that these figures be substantially increased, since the apparent stresses are probably very much less than the actual and local stresses which have led to failure. In conclusion 5, in which Mr. Milton says that temperatures of 300 deg. to 400 deg. C. "do not affect sensibly the ordinary physical properties," they would point out that these temperatures do, in eliminating the effect of cold work, reduce the tensile strength of brasses such as those under investigation. The paper given by Mr. Ellis in February, 1919, has been particularly helpful.*

The flower-bowl which has formed the subject of the investigation was probably pressed and spun from a disc of rolled sheet, and was most likely annealed at successive stages of cold work, and then no doubt finally hammered to give the pattern. As pointed out during the account of the investigation, it was left in a quite hard, cold-worked condition. Our inquiries lead us to the conclusion that the brass in the upper portion of the bowl was internally stressed to such a degree that it only needed minor corrosion effects to lead to the local concentration of stress to provide stresses within the material which it could not reasonably be expected to withstand. Hence the production of the cracks. It may be, and indeed there are numerous instances of season cracking on record pointing in that direction, that corrosion was not necessary, the stresses left in the material being already sufficiently great to produce rupture without the aid of corrosion. Our inquiries lead us to the conclusion that intrinsically the brass from which the article was made was not of an unsatisfactory composition, and, further, that if, instead of being left in the hard, cold-worked condition, the bowl had been suitably annealed, cracking would not have taken place. We do not intend in these observations to be the least dogmatic, but if the subject is to be carried any further, it is necessary that we state the conclusions which we are led to draw from our investigations. It may be useful at this stage to add that the formation of cracks was particularly noticeable in those parts of the bowl in which the work was most uneven and severe. Incidentally also corrosion seemed to have been set up to a greater extent where the cold working had been most severe.

It may be useful to recapitulate a few of the essential facts. The cracks were mostly vertical and invariably in the cold-worked sides, whilst the bottom of the bowl, which was practically unworked, showed no evidence of cracking. The fractures were essentially between the crystals. There was evidence to show that the cracks had invariably started from the outside of the bowl.

The authors have occasionally seen it stated that recrystallisation may be brought about in such brassware at atmospheric temperatures: they have no evidence in this direction, and their experience with the experimental spun cups would lead them to discountenance, in the absence of better evidence, the possibility of such low-temperature annealing in brass.

Theoretical Considerations.—Investigators have, from time to time, made much of the fact that metals have fractured between the crystals. In view of the wide discussion which has taken place upon Dr. Rosenhain's theory as to the existence of an intercrystalline film of amorphous material, the authors feel that the whole question should be reconsidered. Personally, they are unable to accept this theory of the existence of an amorphous film between the crystals in cast or truly annealed metal. They wish, however, to make their position perfectly clear with regard to the amorphous theory generally. Sir George Beilby, F.R.S., in his classical researches upon the films produced on the surfaces of metal by polishing, established, in their opinion, the existence of amorphous metal. They are prepared to accept the extension of the theory to the effect that in cold-worked material the amorphous phase is brought into existence by the breaking down of the crystals. Whether some of the crystal debris can be truly proved to be the amorphous phase is perhaps at present a little doubtful, but it is obvious to the authors, in the light of several investigations conducted at the Brown-Firth Research Laboratories in recent years, that the physical properties of cold-worked material, as originally indicated by Sir George Beilby and other workers, are entirely different from those of the crystalline metals from which they are produced. The authors therefore accept, for guidance in their investigatory work, the amorphous theory as applied to cold-worked materials. When, however, they come to the existence and properties of an amorphous phase left between the crystals after crystallisation, as suggested by Dr. Rosenhain, F.R.S., and others, they must confess that they are extremely sceptical. Their scepticism has been increased by the extended use made of that theory by Dr. Rosenhain and Mr. Archbutt† in explanation of the phenomenon of season cracking. The authors appreciate the ingenuity of the theory advanced, but unfortunately fail to be able to reconcile it with the facts which have come to their notice in the course of this and other investigations.

To revert now to the actual production of season cracks. The authors are satisfied that they have shown, as has for some time been understood, that cracking is brought about in articles which are highly stressed, stresses having been proved, according to their investigation, which are well up towards the maximum stress in tons per square inch which the material will stand without rupture. It is therefore not feasible in such an instance to employ a theory devised to explain rupture produced by small stresses such as those which apparently Dr. Rosenhain and Mr. Archbutt have in mind in their investigation, to which reference has just been made. Since season cracks result from the outer layers of spun articles, which skin is under tension and other stresses, it is perhaps useful at this stage carefully to consider the mechanism of the tensile test. If a stress-strain diagram of a ductile metal is studied it will be seen that the strain is proportional to the stress until the elastic limit is reached. When the elastic limit is passed then plastic deformation takes place, and it must be remembered that in spinning we are already well within that range. If we follow the stress-strain diagram still further we shall find that we arrive at the maximum load borne by the specimen, which load is not, however, in some ductile metals, the load which is necessary to produce rupture, it being found that a very much less load is actually responsible for the final break. In spinning it would appear that stresses left in the material approximate to or, at any rate, are within reasonable distance of the maximum load which the material will bear, and it is therefore clear that if any discontinuity is introduced into the external surface, either through corrosion or other causes, the stresses will readily be accentuated sufficiently to produce rupture. (Compare mercurious nitrate experiments, page 456.)

We must now consider the very interesting experiments with aluminium alloys described by Rosenhain and Archbutt. They take an aluminium sheet, bend it over a large radius to nearly 180 deg., secure it in position and, according to the condition of the material, the time varies which is required to produce rupture. Those aluminium alloy sheets, if the stresses are released, do not go back to the straight, but remain deformed, and hence it is clear that the elastic limit of the material has been substantially exceeded, with considerable local plastic deformation, and with the additive stresses the authors would consider that the conditions are such as to place the material in such a highly stressed condition that the skin stresses approximate to the maximum stress which the material would ordinarily withstand in tension.

We now come to consider the question as to whether the load, which is a little less than the maximum stress indicated in the stress-strain diagram, can be, under given conditions, sufficient to produce rupture. In other words, if we performed a tensile test over a period of hours or years instead of over 30 seconds to 60 seconds, would a maximum load, lower (although well up the plastic deformation range) than the maximum load which the material could bear under the normal conditions of the tensile test, produce rupture if maintained on the specimen for a sufficient length of time, free from corrosive and other damaging influences? The time would, presumably, vary with the properties of the materials, elastic limit, maximum stress, ductility, &c. This aspect of matters is receiving serious attention in our laboratories, and is a part of the whole problem as to how the speed with which, and the condition under which, the stresses are applied modifies the response made by the material.

Rosenhain and Archbutt, in their paper to which reference has already been made, suggest that "failure after lapse of time under stresses below the maximum stress of the material" are not uncommon throughout the range of metallurgy, and illustrate their comments with examples of lead, brass, aluminium alloys and steel. The authors are prepared to concede that "apparent" failure under such conditions appears to take place, but they are inclined to think that such anomalous phenomena will cease to be anomalous in the sense under discussion with a more complete knowledge of the stresses and the conditions under which the stresses act in the several cases. Consideration of such failures in steel will be left for the moment, and will probably be dealt with elsewhere, and, for the moment, it is intended to consider the Rosenhain and Archbutt theory as applied to season cracking in brass. The theory can best be explained in their own words:—

"The explanation of the intercrystalline fracture of certain metals resulting from prolonged exposure to stress which the authors desire to put forward for consideration may then be stated as follows: That the constituent crystals of a metal are held together by an amorphous intercrystalline cement, which, in some metals, at all events, is sufficiently mobile to yield to the tendency of any applied stress to produce flow. In such cases it would follow that intercrystalline rupture must occur, after the lapse of sufficient time, as the result of the prolonged action even of small stresses, which may arise either from externally-applied forces or from elastic deformation and consequent internal stresses. It would seem, at first sight, that such an explanation covers too much, since it would suggest the probability that intercrystalline failure would ultimately occur in all metals as the result of prolonged exposure to stresses far below their ordinary breaking stresses. Experience clearly indicates that this is not the case, since metal structures of various kinds are shown to have withstood considerable and continued stresses for very long periods. Cases of 'season cracking' are, in fact, rather exceptional and isolated. This consideration shows that the explanation, as stated above, is incomplete, and the authors believe that the completion is to be found in a consideration of the conditions existing at a crystal boundary, where a tendency exists for gradual flow of the 'cement' under prolonged application of stress."

They endeavour to make the above idea complete by suggesting that the external shape of the crystal is the key to the operation of the above mechanism, and give interesting examples of the effect of smooth as against rugged externals, and state that fracture on the lines indicated "should only occur where the crystal boundaries have assumed smooth and regular outlines." For instance, they claim that season cracking is most fully developed by over-annealing, by which the authors

* Sheffield Society of Engineers and Metallurgists, 1916
† Institute of Marine Engineers, 1917.

* Journal of the Birmingham Metallurgical Society, February, 1919.
† Royal Society, March, 1919.

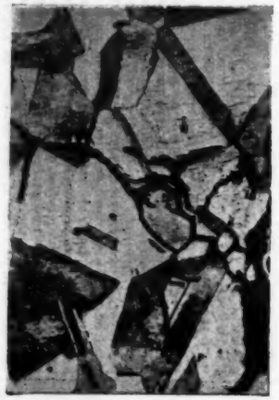


FIG. 10. × 500. Etched.

FIG. 11. × 500. Etched.

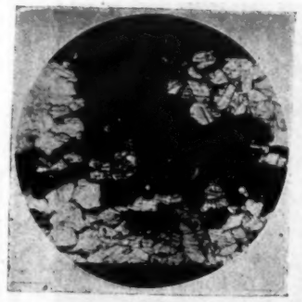


FIG. 14.—Shewing corrosion at commencement of crack. × 100. Etched. Reduced by one-third.

FIG. 18. × 100. Etched. Reduced by one-third.

FIG. 12.—Portions of vertical crack. × 500. Etched.

FIG. 13.—Portions of another crack. × 500 Etched.

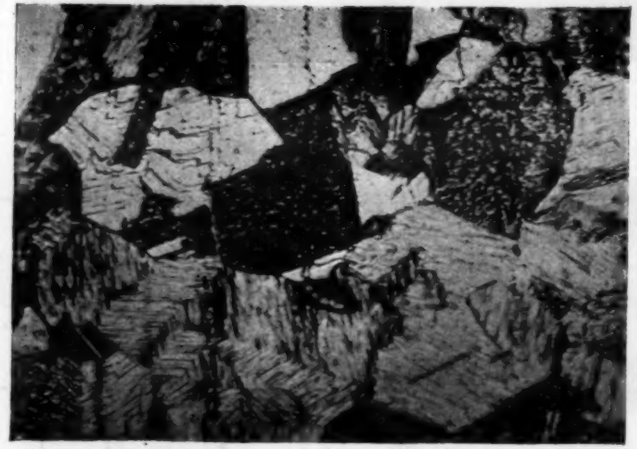


FIG. 15.—Brass from walls of pot annealed at 450° C. × 1000. Etched. Reduced by one-third.

FIGS. 10–13 reduced by one-fourth.

presume is meant complete recrystallisation, whereas by annealing, the stresses are removed and the danger of season cracking eliminated. The theory under discussion is dependent upon the existence of the amorphous phase or under-cooled liquid of the metal between the crystals, and Rosenhain and Archbutt attribute to such an under-cooled liquid phase physical and mechanical properties which are useful in supporting their theory. What, however, are the facts concerning the under-cooled liquid or the amorphous phase of cold-worked metals?

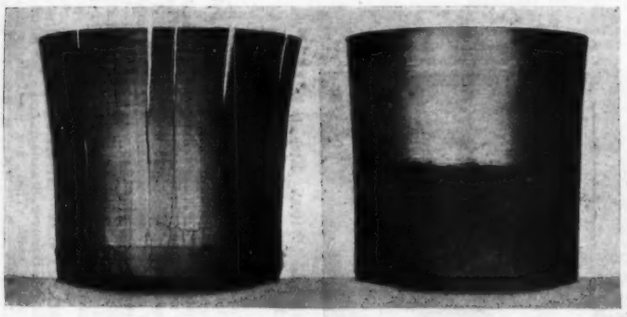
The amorphous phase as produced by cold work—assuming the validity of the hypothesis that the amorphous phase is produced by cold work—is the only concrete instance of metal in that condition, and on the amorphous theory we endeavour to explain the physical and mechanical properties of cold-wrought metals. Rosenhain and Archbutt might, therefore, refer to such data for an insight into the properties of their amorphous film, and if they do they will find little support for the physical properties which they have postulated. Cold-drawn steel or other metallic wires of high tensile strength induced by cold work will unquestionably resist very high stresses indefinitely, provided such stresses are within the extremely wide elastic range associated with such material. Hence, to cite only the one instance, the amorphous phase does not contribute to the rupture of the material; so much so, in fact, that such cold-worked wire, containing, hypothetically, a considerable portion of the amorphous under-cooled liquid phase, will withstand indefinitely stresses far greater than those which the unworked material will bear. Further, the hypothetically amorphous film suggested by Rosenhain is only a few atoms thick, whereas if the amorphous theory as applied to cold-worked materials is to stand, there must be present a more substantial mass of this phase, and hence the very action which Rosenhain and Archbutt postulate should be facilitated, and it is not.

Though important, the effect of the time factor in modifying the breaking load of the material, when quantitatively measured, would not provide an anomaly in the field of physics, and the authors know, as the result of other experiments in ferrous research, that materials will sustain stresses momentarily which they will not withstand over longer periods of time in the case of materials which do not break with an inter-crystalline fracture. Such statement of fact is, however, a widely different matter to the hypothesis put forward by Rosenhain and Archbutt.

With regard to cold-worked brass, the authors consider that such material will safely withstand indefinitely stresses considerably higher than the unworked material. They consider that season cracking is in effect due to the fact that stresses have been put upon the material, at any rate locally, of such a high order that the normal breaking-down point of such cold-worked material has been reached.

In conclusion, the authors desire to record their appreciation of the interest taken in the investigation by Messrs. Bolsover, Stanfield, and other members of the laboratory staff. They are particularly indebted to Mr. George Stanfield, B.Sc., M.Eng., for his suggestion of the method adopted in determining the stresses due to cold work, and also to Messrs. William Hutton and Sons, Limited, for their help in the spinning experiments. They much appreciate the interest taken in the work by

SEASON CRACKING IN BRASS.



(*a*) (*b*)

Fig. 16.—(*a*) Spun and placed in $HgNO_3$ solution.
(*b*) Annealed and placed in $HgNO_3$ solution.

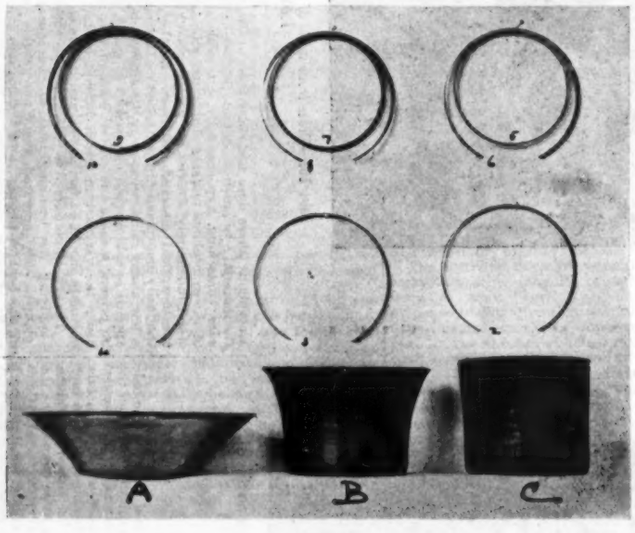
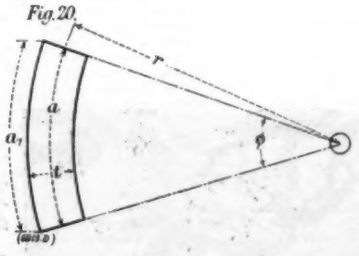


Fig. 17.—Illustrative of Stress experiments.

Fig. 19. × 500. Etched.
Reduced by one-fourth.

Fig. 20.



Mr. F. C. Fairholme, and thank Messrs. Thomas Firth and Sons, Limited, and Messrs. John Brown and Co., Limited, for their permission to publish the results of the investigations.

APPENDIX I.

Method of Calculating Stress.

The fact that rings parted off from the bowl, and afterwards cut, open out to a larger curvature, proves that when in their positions on the bowl the material is only kept in the shape which then obtains by the constraint put upon it by the neighbouring parts. Thus there may exist compression or tension circumferentially or vertically, as well as bending stresses in both directions. By cutting up the bowl in various ways and observing the change of shape on small pieces on freeing them from the remainder of the bowl, the stresses in these different directions can be estimated.

Of these, the circumferential bending appears to be the most serious, and the calculation which follows is based on simple bending of the horizontal rings, other stresses being neglected. The presence of the other stresses would modify slightly the actual resultant stress at any point, increasing it in some cases and reducing it in others.

Since the application of the formula deduced requires a knowledge of the value of the modulus of elasticity of the material, this value was determined by a deflection experiment, using a strip of the material supported at each end, and having known weight hung from the middle. The value deduced was 7,500 tons per square inch.

1. Piece naturally straight, bent to the arc of a circle of radius r, Fig. 20, assuming the stresses to be within the elastic limit.

t = thickness.
E = modulus of elasticity.
a = length of arc.
r = radius of curvature at centre line.
ϕ = angle of deflection in radians.

$$a = \phi r \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

For the outer surface, a then becomes a_1 after bending.

$$a_1 = \left(r + \frac{t}{2}\right)\phi.$$

$\therefore$ Increase of length $= a_1 - a = \frac{t}{2}\phi.$

$$\text{But } E = \frac{\text{stress}}{\text{strain}} = \frac{\text{load per unit area}}{\text{elongation} \div (\text{original length})}$$

$$\therefore \text{Stress} = \frac{E \times \text{elongation}}{\text{original length}}$$

$$\text{Stress} = \frac{E \times \frac{t}{2}\phi}{r\phi} = \frac{Et}{2r} \quad . \quad . \quad (2)$$

2. Piece naturally curved, but kept to a different curvature by some means.

$$\text{Stress} = \frac{Et}{2} \times \text{change of curvature.}$$

$$= \frac{Et}{2}\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$$

$$= \frac{Et}{2}\left(\frac{r_1 - r_2}{r_1 r_2}\right)$$

If W = width of opening (measured along the arc of the circle) after releasing the stresses.

$$W = 2\pi r_1 - 2\pi r_2 = 2\pi(r_1 - r_2)$$

$$\therefore \text{stress} = \frac{EtW}{4\pi r_1 r_2}.$$

North of Ireland Shipbuilding.—The recently abandoned Admiralty controlled shipyard at Warrenpoint, County Down, has been purchased by a group of leading men from Belfast, Liverpool, and Glasgow, the principals being Mr. John Sinclair, of Glasgow, and Mr. Alfred Rowland, of Liverpool.

Corrosion and Stress.—In a paper recently read before the American Society for Testing Materials, Messrs. P. D. Merica and R. W. Woodward state that investigations have shown that brass rods subjected to the action of concentrated ammonium hydroxide would break under stresses exceeding the yield-point with very little elongation.

The Ageing of Test-Pieces.—In a paper published in the Bulletin of the American Institute of Mining and Metallurgical Engineers, Messrs. G. A. Reinhardt and H. L. Cutler state that in making acceptance tests of a moderately hard steel better results were obtained if the test-pieces were allowed a day's rest between the time they were machined and the time they were tested.

The 8-Hour Day in France.—Representatives of the metallurgical, mining, mechanical construction, electrical and manufacturing employers' union, and of the Federation of Metal Workers of France, have agreed upon the following conditions: There shall be an 8-hour day in all these industries. The employees will adapt themselves to the modern developments in machinery and to reasonable methods of work in order that production may early resume its former status and attain the proportions necessary to the general welfare. The employers recognise that in order to maintain and develop production it is expedient to establish piece rates, premiums and bonuses, and they agree to guarantee a wage based upon production under normal conditions; and if, by reason of the activity and efforts of the employees, production exceeds this base, the employees are assured that their intensified production shall not be considered as a reason for a reduction in wages. The reduction of the hours of labour to eight per day shall not mean a decrease in wages. Employees working by the hour shall have compensating increase on hourly rates, but changes in piece rates shall be demanded only when such rates, without change in equipment, do not afford, with normal effort, an opportunity to earn the usual wages.

THE MAGNETISATION OF A ROTATING BODY.

*How could a Rotating Body such as the Sun become a Magnet?**

By Sir Joseph Larmor.

The obvious solution by convection of an electric charge, or of electric polarisation is excluded; because electric fields in and near the body would be involved, which would be too enormous. Direct magnetisation is also ruled out by the high temperature, notwithstanding the high density. But several feasible possibilities seem to be open.

(1) In the case of the sun, surface phenomena point to the existence of a residual internal circulation mainly in meridian planes. Such internal motion induces an electric field acting on the moving matter: and if any conducting path around the sola axis happens to be open, an electric current will flow round it, which may in turn increase the inducing magnetic field. In this way it is possible for the internal cyclic motion to act after the manner of the cycle of a self-exciting dynamo, and maintain a permanent magnetic field from insignificant beginnings, at the expense of some of the energy of the internal circulation. Again, if a sunspot is regarded as a superficial source or sink of radial flow of strongly ionised material, with the familiar vortical features, its strong magnetic field would, on these lines, be a natural accompaniment: and if it were an inflow at one level compensated by outflow at another level, the flatness and vertical restriction of its magnetic field would be intelligible.

(2) Theories have been advanced which depend on a hypothesis that the force of gravitation or centrifugal force can excite electric polarisation, which, by its rotation, produces a magnetic field. But, in order to obtain sensible magnetic effect, there would be a very intense internal electric field such as no kind of matter could sustain. That, however, is actually got rid of by a masking distribution of electric charge, which would accumulate on the surface, and in part in the interior where the polarisation is not uniform. The circumstance that the two compensating fields are each enormous is not an objection; for it is recognised, and is illustrated by radioactive phenomena, that molecular electric fields are, in fact, enormous. But though the electric masking would be complete, the two distributions would not compensate each other as regards the magnetic effects of rotational convection: and there would be an outstanding magnetic field comparable with that of either distribution taken separately. Only rotation would count in this way; as the effect of the actual translation, along with the solar system, is masked by relativity.

(3) A crystal possesses permanent intrinsic electric polarisation, because its polar molecules are orientated: and if this natural orientation is pronounced, the polarisation must be nearly complete, so that if the crystal were of the size of the earth it would produce an enormous electric field. But, great or small, this field will become annulled by masking electric charge as above. The explanation of pyro-electric phenomena by Lord Kelvin was that change of temperature alters the polarisation, while the masking charge has not had opportunity to adapt itself: and piezo-electric phenomena might have been anticipated on the same lines. Thus, as there is not complete compensation magnetically, an electrically neutralised crystalline body moving with high speed of rotation through the æther would be expected to produce a magnetic field: and a planet whose materials have crystallised out in some rough relation to the direction of gravity, or of its rotation, would possess a magnetic field. But relativity forbids that a crystalline body translated without rotation at astronomical speeds should exhibit any magnetic field relative to the moving system.

The very extraordinary feature of the earth's magnetic field is its great and rapid changes, comparable with its whole amount. Yet the almost absolute fixity of length of the astronomical day shows extreme stability of the earth as regards its material structure. This consideration would seem to exclude entirely theories of terrestrial magnetism of the type of (2) and (3). But the type (1), which appears to be reasonable for the case of the sun, would account for magnetic change, sudden or gradual, on the earth merely by change of internal conducting channels: though, on the other hand, it would require fluidity and residual circulation in deep-seated regions. In any case, in a celestial body residual circulation would be extremely permanent, as the large size would make effects of ordinary viscosity nearly negligible.

The Swedish Telephone Service.—Although the Swedish telephone service on the whole may be regarded as a model for other countries, the war naturally has exercised a deterrent effect upon fresh developments. The Swedish State Telegraphs, however, now that certain necessary materials have become more plentiful, are contemplating large extensions. It is also proposed to transform the large Stockholm telephone system to automatic working, while at the same time the national and Stockholm systems are to be amalgamated. This will take several years to accomplish, and no automatic system has as yet been definitely decided upon. Several systems will be carefully tested. An improvement has been made in the utilisation of the lines, inasmuch as three conversations can now be carried on simultaneously on two inter-urban lines. A new cable is to be laid between Stockholm and Gothenburg for telephonic service.

* Paper read before Section A of the British Association, at Bournemouth.

TEMPER-BRITTLENESS OF NICKEL-CHROME STEEL.*

By R. H. Greaves, M.Sc., F.I.C. (Research Department, Woolwich Arsenal).

With a Further Communication by R. H. Greaves, Muriel Fell, B.Sc. (Research Department, Woolwich Arsenal), and Sir Robert Hadfield, Bart., F.R.S.

"Temper-brittleness" is the term applied by Mr. J. H. S. Dickenson† to the condition induced in nickel-chrome steel by slow cooling from the tempering temperature, and revealed by a low absorption of energy in the single-blow impact test on notched bars.

The effect of slow cooling after tempering on the impact figure is now generally recognised. Reference to this has been made in several recent papers and discussions,* but these references do not adequately reflect the amount of work which has been done on the subject. It is hoped in this communication (which contains the results of experiments made in 1916–17) to present some aspects of the question, but the author's purpose would be largely fulfilled if the paper serves to promote an interchange of views on the subject.

Steels Used.—(See table on page 462.) All were made by the acid open-hearth process. A and B were hollow forged: ratio of initial to final cross-section, 7·5; ratio of initial to final external diameter, 2·4. C was solid forged: ratio of initial to final cross-section, 2·2.

TABLE I.

Steel and Treatment.	Elastic Limit. Tons per Sq. In.	Yield-Point. Tons per Sq. In.	Maximum Load. Tons per Sq. In.	Elongation per Cent. on 2 In.	Reduction of Area per Cent.	Fracture.	Brinell Hardness Number.	Guillery Impact Figure. Mesnager Notch. Kgm.	Guillery Impact Figure. ¼ Mm. V-Notch. Kgm.	Approximate Izod Figure. Ft.-Lb.
A 1	22	32·8	45·5	23·5	40	Fibrous	221	13·4	10·6	73
2	27	32·8	44·4	25·5	55	Fibrous, ¼-cup ..	215	7·3	3·4	35
3	30	30·1	51·8	17·0	34	Fibrous	247	12·8	9·4	70
4	28	37·4	49·3	19·0	39	Fibrous	234	3·6	2·2	12
B 1	17	30·0	47·6	24·0	47	Fibrous	236	11·0	7·0	58
2	15	28·0	45·5	24·0	50	Fibrous, laminated ..	221	7·9	4·9	39
3	26	35·3	48·9	21·0	49	Fibrous	234	11·5	9·2	62
4	27	36·1	48·5	18·0	36	Fibrous, laminated ..	226	6·2	4·7	29
C 3	20	33·9	47·7	21·0	50	Fibrous, laminated ..	220	7·6	—	37
4	20	31·7	47·1	21·0	43	Fibrous, laminated ..	217	4·2	—	16
5	25	37·0	48·6	21·0	51	Fibrous, laminated ..	223	8·2	—	41
6	27	34·7	46·5	19·0	45	Fibrous, laminated ..	214	4·3	—	17
7	35	43·6	52·4	20·0	50	Fibrous	250	2·5	—	6
8	33	43·1	52·1	17·0	34	Fibrous	244	7·8	—	39
9	20	34·1	49·1	16·5	32	Fibrous, laminated ..	226	8·9	—	45
15	30	30·1	48·8	19·0	44	Fibrous	231	2·4	—	6
17	29	37·4	47·1	20·0	47	Fibrous	221	6·2	—	29

Fig. 1. STEEL A. GUILLERY IMPACT TESTS.

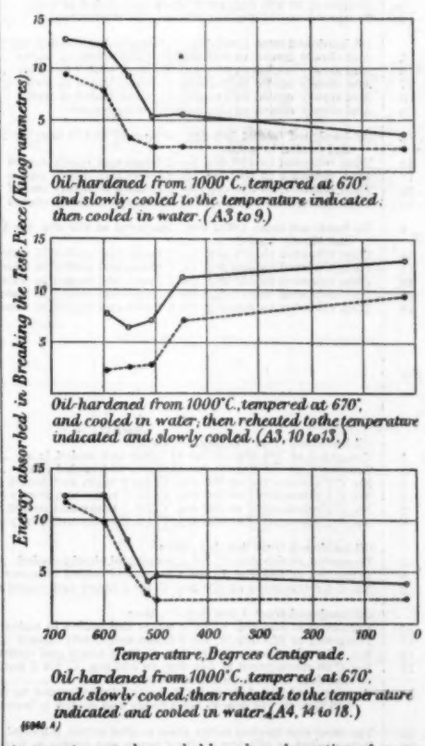
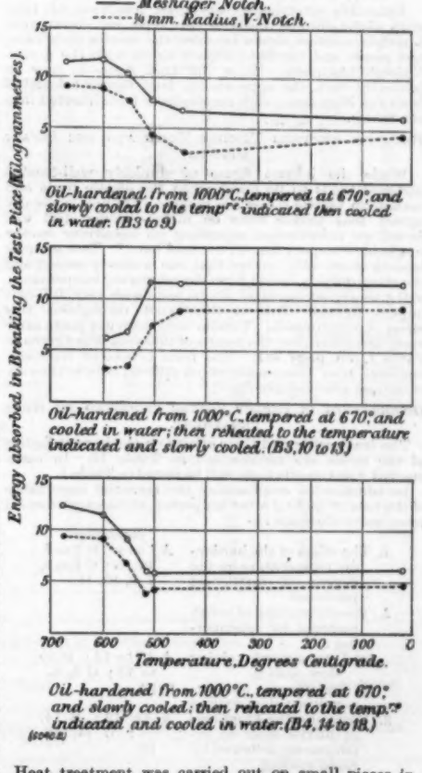

Mesnager Notch.
¼ mm. Radius, V-Notch.
Energy absorbed in Breaking the Test-Piece (Kilogrammetres).
15
10
5
Oil-hardened from 1000° C., tempered at 670°, and slowly cooled to the temperature indicated, then cooled in water. (A3 to 9.)
Oil-hardened from 1000° C., tempered at 670°, and cooled in water; then reheated to the temperature indicated and slowly cooled. (A3, 10 to 13.)
700 600 500 400 300 200 100 0
Temperature, Degrees Centigrade.
Oil-hardened from 1000° C., tempered at 670°, and slowly cooled; then reheated to the temperature indicated and cooled in water. (A4, 14 to 18.)

Fig. 2. STEEL B. GUILLERY IMPACT TESTS.


Mesnager Notch.
¼ mm. Radius, V-Notch.
Energy absorbed in Breaking the Test-Piece (Kilogrammetres).
15
10
5
Oil-hardened from 1000° C., tempered at 670°, and slowly cooled to the temperature indicated, then cooled in water. (B3 to 9.)
Oil-hardened from 1000° C., tempered at 670°, and cooled in water; then reheated to the temperature indicated and slowly cooled. (B3, 10 to 13.)
700 600 500 400 300 200 100 0
Temperature, Degrees Centigrade.
Oil-hardened from 1000° C., tempered at 670°, and slowly cooled; then reheated to the temperature indicated and cooled in water. (B4, 14 to 18.)

Heat treatment was carried out on small pieces in the laboratory. The pieces were heated for hardening in a muffle furnace, and were in each case kept at the maximum temperature for 1 hour before quenching in oil. The tempering treatments were done in a steel muffle the temperature of which could be kept uniform and could be readily controlled. The tempering tempera-

* Metallurgical Communication No. 1 from the Research Department, Woolwich, submitted at the meeting of the Iron and Steel Institute, on Friday, September 19, 1919.

† Dickenson, *Journal of the Institution of Automobile Engineers*, 1917–18, vol. xii, page 342 (discussion of paper by Philpot).

* Brearley, *Journal of the Institution of Automobile Engineers*, 1916–17, vol. xi, page 347; Philpot, *ibid.*, page 340; Hatfield, *Proceedings of the Institution of Mechanical Engineers*, May, 1919; Hayward, *Metallurgical and Chemical Engineering*, 1919, page 519.

Table of Particulars of Steels Used.

Steel.	A.	B.	C.
	per cent.	per cent.	per cent.
Carbon	0·24	0·27	0·27
Silicon	0·20	0·12	0·18
Manganese	0·49	0·43	0·58
Sulphur	0·029	0·027	0·035
Phosphorus	0·022	0·022	0·023
Nickel	3·54	3·71	3·54
Chromium	0·59	0·65	0·77

tures and rates of cooling were recorded by a Callendar recorder working in conjunction with a platinum resistance thermometer. The temperatures given below were subject to slight variations, but may be taken as correct to ± 5 deg. C. "Slow cooling" refers to cooling in the furnace at a nearly uniform rate of ¾ deg. to 1 deg. C. per minute.

Tests applied to Heat-Treated Material included.

1. Tensile tests on test-pieces of the following dimensions :—

	In.
Diameter	0·564
Gauge length	2·00
Parallel	2·25

Extensions were measured during loading with the Ewing extensometer reading to $\frac{1}{125,000}$ in. The yield-point was taken as the load giving an extension of 0·01 in. with the load on (*i.e.*, about 0·004 in. permanent extension for these nickel-chrome steels).

2. Brinell tests with the 10-mm. ball and 3,000 kg. load, or the 5-mm. ball and 750 kg. load.

3. Single-blow impact tests on notched bars. The impact figures given in this paper represent the average of two or more determinations of the actual energy absorbed in breaking the test-piece at the notch (*i.e.*, over a cross-sectional area of 0·8 sq. cm.). All the tests were made on the Guillery machine at a striking energy of 60 kilogrammetres. The test-piece, 10 mm. square and 56 mm. long, bridges a gap 40 mm. wide, and is struck in the middle on the side opposite the notch. Two forms of notch were used :—

Mesnager notch.	Drilled.	1 mm. radius. 2 mm. deep.
¼ mm. V-notch.	Milled.	45 deg. V. with root radius of ¼ mm. 2 mm. deep.

Extensive experience, based on hundreds of tests with nickel-chrome steels of this type, has shown that a simple relation exists between the results with these test-pieces and the Izod impact figure with the ¼-mm. V-notch test-piece. Since the Izod figure is now so generally used, the approximate Izod figures calculated from the Mesnager notch results have been inserted into the tables.

Relation between Tensile Tests and the Impact Figure.

While the impact figure of similarly well-treated material tends to be lower when the elastic limit and maximum tensile stress are greater, it is now generally agreed that tensile tests on nickel-chrome steel will reveal no information regarding its behaviour in the single-blow impact test on notched bars.* Two samples treated identically, except that one is slowly cooled and the other quickly cooled from the tempering temperature, will give almost identical tensile tests with very different impact figures. This is illustrated throughout this series of experiments. Tensile tests were not made after every treatment, but the results of those made are given in Table I, on page 461. The tests bracketed represent material after treatments which differed only in the rate of cooling after tempering.

Differences in Impact Figure produced by Heat Treatment.

The treatments and their effects on the impact figures of the steels are summarised in Table II. In cases marked * the tensile tests will be found in Table I.

In addition to emphasising the essential importance of the rate of cooling after tempering, these experimental treatments illustrate :—

	Examples.
1. The effect of the hardening temperature on the degree of brittleness produced	A 1 to 4 ; B 1 to 4, 3a, 4a ; C 1 to 6, 7, 8, 10, 11.
2. The embrittling of tough material by retempering :	
(a) Treatments involving slow cooling	A 10 to 13 ; B 10 to 13 ; C 4, 6.
(b) Treatments not involving slow cooling	C 12.
3. Restoring the toughness of brittle steel by retempering, followed by rapid cooling	A 14, 15 ; B 14, 15 ; C 13, 16, 18.
4. The determination of the temperature range in which brittleness is produced	A 5 to 18 (Fig. 1) ; B 5 to 18 (Fig. 2) ; C 12, 16.

Summary and Conclusions.

The results of the experimental heat treatments described in this paper indicate that in the case of nickel-chrome steels containing about 0·25 per cent. carbon 0·5 per cent. manganese, 3·5 per cent. nickel, and 0·6 per cent. chromium :—

1. Wide differences in the impact figure with almost identical tensile tests can be produced by suitable heat treatment.

2. After hardening, every tempering treatment involving a final rapid cooling from 600 deg. C. or above produced good impact figures.

3. Every tempering treatment involving a final slow cooling from a similar temperature produced a considerably lower and often a very bad impact figure.

4. Steels of almost identical composition may vary in the degree of brittleness produced by identical treatment.

5. In any given steel the degree of brittleness which can be produced by identical conditions of tempering depends on the original hardening temperature. The impact figure after slow cooling from the tempering temperature is lower, the higher the temperature of hardening.

6. Reheating to a temperature in the neighbourhood of 520 deg. C. results in brittleness, whatever the subsequent rate of cooling.

7. Tough steel of this composition can be made brittle by reheating to this temperature, or by reheating to any higher tempering temperature followed by slow cooling.

8. Brittle steel can be restored by reheating to between 600 deg. and 670 deg. C. and cooling rapidly. (Treatments in sections 6, 7 and 8 involve a slight reduction of the tensile properties corresponding to the effect of the additional tempering treatment.)

9. These results are in accordance with the assumption

TABLE II.

No.	Treatment.	Brinell Hardness Number.	Guillery Impact Figure. Mesnager Notch. Kgm.	Guillery Impact Figure. ¼ Mm. V-Notch. Kgm.	Approximate Equivalent Izod Figure. Ft.-Lb.
	Steel A.				
	Water-hardened from 850 deg. C., then				
A 1	Tempered at 675 deg. for 8½ hours and cooled in water	221*	13·4	10·6	73
2	Tempered at 675 deg. for 8½ hours and slowly cooled	215*	7·8	3·4	35
	Oil-hardened from 1,000 deg. C., then				
3	Tempered at 670 deg. C. for 2 hours and cooled in water	247*	12·8	9·4	70
4	Tempered at 670 deg. C. for 2 hours and slowly cooled	234*	3·6	2·2	12
	Oil-hardened from 1,000 deg. C., tempered at 670 deg. for 2 hours,				
5	And slowly cooled to 600 deg. C., then cooled in water	231	12·4	7·8	67
6	And slowly cooled to 550 deg. C., then cooled in water	230	9·3	3·1	48
7	And slowly cooled to 502 deg. C., then cooled in water	239	5·1	2·3	22
8	And slowly cooled to 446 deg. C., then cooled in water	233	5·4	2·4	24
9	And slowly cooled to atmospheric temperature	234	3·6	2·2	12
3	Oil-hardened from 1,000 deg. C., tempered at 670 deg. for 2 hours, and cooled in water from 670 deg. C.	247	12·8	9·4	70
10	Then reheated to 450 deg. for 2 hours and slowly cooled	248	11·2	7·0	60
11	Then reheated to 508 deg. for 2 hours and slowly cooled	245	7·0	2·7	34
12	Then reheated to 554 deg. for 2 hours and slowly cooled	232	6·1	2·5	28
13	Then reheated to 598 deg. for 2 hours and slowly cooled	236	7·6	2·2	31
4	Oil-hardened from 1,000 deg., tempered at 670 deg. for 2 hours and slowly cooled	234	3·6	2·2	12
14	Then reheated to 675 deg. and cooled in water	228	12·2	11·9	66
15	Then reheated to 600 deg. and cooled in water	223	12·4	9·9	67
16	Then reheated to 556 deg. and cooled in water	228	8·0	5·2	40
17	Then reheated to 517 deg. and cooled in water	233	4·0	2·9	15
18	Then reheated to 500 deg. and cooled in water	232	4·6	2·3	19
	Steel B.				
	Water-hardened from 850 deg. C., then				
B 1	Tempered at 675 deg. for 8½ hours, and cooled in water	236*	11·0	7·0	58
2	Tempered at 675 deg. for 8½ hours, and slowly cooled	221*	7·9	4·9	39
	Oil-hardened from 1,000 deg. C., then				
3	Tempered at 670 deg. for 2 hours and cooled in water	234*	11·5	9·2	62
4	Tempered at 670 deg. for 2 hours and slowly cooled	226*	6·2	4·7	29
	Oil-hardened from 1,100 deg. C., then				
3a	Tempered at 670 deg. for 2 hours and cooled in water	235	11·2	—	60
4a	Tempered at 670 deg. for 2 hours and slowly cooled	229	5·0	—	21
	Oil-hardened from 1,000 deg. C., tempered at 670 deg. for 2 hours,				
5	And slowly cooled to 600 deg. C., then cooled in water	224	11·8	9·0	63
6	And slowly cooled to 550 deg. C., then cooled in water	220	10·4	7·9	55
7	And slowly cooled to 502 deg. C., then cooled in water	226	7·9	4·5	39
8	And slowly cooled to 446 deg. C., then cooled in water	239	6·8	2·0	32
9	And slowly cooled to atmospheric temperature	226	6·2	4·7	29
3	Oil-hardened from 1,000 deg., tempered at 670 deg. for 2 hours, and cooled in water	234	11·5	9·2	62
10	Then reheated to 450 deg. for 2 hours and slowly cooled	231	11·5	8·8	62
11	Then reheated to 508 deg. for 2 hours and slowly cooled	229	11·5	7·2	62
12	Then reheated to 554 deg. for 2 hours and slowly cooled	219	6·8	3·5	32
13	Then reheated to 598 deg. for 2 hours and slowly cooled	228	6·1	3·2	28
4	Oil-hardened from 1,000 deg., tempered at 670 deg. for 2 hours, and slowly cooled	226	6·2	4·7	29
14	Then reheated to 675 deg. for 2 hours and cooled in water	226	12·4	9·4	67
15	Then reheated to 600 deg. for 2 hours and cooled in water	220	11·5	9·2	62
16	Then reheated to 556 deg. for 2 hours and cooled in water	225	9·1	6·9	47
17	Then reheated to 517 deg. for 2 hours and cooled in water	229	6·0	3·8	27
18	Then reheated to 500 deg. for 2 hours and cooled in water	225	5·8	4·2	26

No.		Brinell Hardness Number.	Guillery Impact Figure. Mesnager Notch. Kgm.	Approximate Izod Impact Figure. Ft.-Lb.
	Steel C.			
	Oil-hardened from 810 deg. C., then			
C 1	Tempered at 705 deg. C. for 1½ hours and cooled in air	249	6·6	31
2	Tempered at 705 deg. C. for 1½ hours and cooled in oil	252	6·4	30
3	No. C 1 retempered at 600 deg. C. for 2 hours and cooled in water	220*	7·6	37
4	No. C 1 retempered at 600 deg. C. for 2 hours and slowly cooled	217*	4·2	16
5	No. C 2 retempered at 600 deg. C. for 2 hours and cooled in water	223*	8·2	41
6	No. C 2 retempered at 600 deg. C. for 2 hours and slowly cooled	214*	4·3	17
	Oil-hardened from 900 deg., then			
7	Tempered at 655 deg. C. for 2 hours and slowly cooled	250*	2·5	6
8	Tempered at 655 deg. C. for 2 hours and cooled in water	244*	7·8	39
9	No. C 8 retempered at 670 deg. C. for 2 hours and cooled in water	226*	8·9	45
	Oil-hardened from 1,000 deg. C., then			
10	Tempered at 655 deg. C. for 2 hours and cooled in water	257	7·8	38
11	Tempered at 655 deg. C. for 2 hours and slowly cooled	258	1·1	4
12	No. C 10 retempered at 515 deg. C. for 4 hours and cooled in water	260	2·1	5
13	No. C 10 retempered at 500 deg. to 550 deg. C. for 4 hours, raised quickly to 650 deg. C., and cooled in water	265	5·8	27
14	Tempered at 650 deg. C. for 2 hours, slowly cooled to 530 deg. C. ; held at 530 deg. to 510 deg. C. for 4 hours and cooled in water	246	1·5	4
15	The steel was treated in the mass to give brittle material, then	231*	2·4	6
16	Retempered at 600 deg. C. for 2 hours and cooled in water	226	6·6	31
17	Retempered at 650 deg. C. for 2 hours and cooled in water	221*	6·2	29
18	Retempered at 675 deg. C. for 3 hours and cooled in water	219	7·4	36

* Philpot, *loc. cit.*, page 288.

that a critical temperature or range of temperatures exists in the vicinity of 550 deg. C., and that above this temperature the tough condition is stable, below this temperature the brittle condition.

The general behaviour of the steel deduced from this assumption is in agreement with the experimental evidence. Slow cooling through the critical temperature results in the production of the stable brittle condition quick cooling retards the change, so that the unstable tough condition is retained. Reheating the tough material to a temperature below the critical temperature results in a reversion to the stable brittle condition, which occurs rapidly at temperatures near the critical range and more slowly at lower temperatures. The effect appears to be practically nil at temperatures below 450 deg. C. Provided the critical temperature is not exceeded, the rate of cooling after this reheating is immaterial. By exceeding the temperature of transformation, the steel, whether tough or brittle, can be obtained again in either condition by quick or by slow cooling.

The author is not aware of any certain method of determining this temperature range other than that of making experimental heat treatments. The laborious nature of this method and the uncertainty of getting equilibrium and uniformity of temperature through the somewhat large masses which have to be used are disadvantageous. Some rapid physical method of determining this dangerous range of temperature in nickel-chrome steels would be of great value.

The author wishes to express his indebtedness to Mr. Harold Moore, O.B.E. (Superintendent Metallurgist, Research Department, Woolwich), for many suggestions made, and valuable advice given during the progress of the work.

He also desires to acknowledge help derived from the views of Mr. J. C. W. Humfrey, and assistance given by Mr. J. A. Jones, B.Sc., in carrying out some of the treatments and tests.

FURTHER COMMUNICATION ON TEMPER-BRITTLENESS OF NICKLE-CHROME STEEL.*

By R. H. GREAVES, M.Sc., MURIEL FELL, B.Sc., and Sir ROBERT HADFIELD, Bart., F.R.S.

FROM a consideration of the results obtained on laboratory-treated pieces of nickel-chrome steels, and described in the preceding paper by one of the authors, a programme was drawn up for the purpose of carrying out experiments on a larger scale. This included :—

Oil-hardening from 850 deg. C., and

A. Tempering at 650 deg. C. and slowly cooling in the furnace.

B. Tempering at 650 deg. C. and cooling in water.

Oil-hardening from 1,000 deg. C., and

C. Tempering at 650 deg. C. and cooling in air.

D1. Tempering at 650 deg. C. and cooling in water.

E1. Tempering at 650 deg. C. and cooling slowly in the furnace.

Reheating of D1 and E1 as follows :—

D2. Reheating the piece D1 to 650 deg. C. and cooling slowly in the furnace.

E2. Reheating the piece E1 to 650 deg. and cooling in water.

Messrs. Hadfield supplied material for the experiment, and the heat treatment was carried out at their works under the direction of Mr. W. E. Parker.

The steel used was an extruded tube, made by the Hadfield process, of the dimensions shown in Fig. 3, on page 464, of the following composition :—

	Per Cent.
Carbon	0·26
Silicon	0·07
Manganese	0·66
Sulphur	0·020
Phosphorus	0·026
Nickel	3·53
Chromium	0·84

REPORT FROM THE HADFIELD RESEARCH LABORATORY WITH REGARD TO TREATMENT.

The entire tube was normalised by heating to 900 deg. C. and cooling in air. It was then cut into two portions, as shown in Fig. 3, the shorter portion being quenched in oil from 850 deg. C. and the longer portion quenched in oil from 1,000 deg. C.

The two portions of the tube in the quenched condition were then cut up into sections transversely, as shown in Fig. 3, and the tempering treatments carried out according to the programme arranged.

A full summary of the treatments is given in Table III.

Brinell hardness tests were made on prepared surfaces on the exterior of the tube after each stage of the treatment, and the figures obtained are shown in the table.

It will be seen from the time-temperature curves of the tempering treatments (Figs. 4 and 5) that in all cases of cooling in the furnace the time of cooling from 600 deg. to 500 deg. C. was 330 minutes, giving an average rate between these limits of about 0·3 deg. C. per minute.

REPORT OF EXAMINATION IN THE RESEARCH DEPARTMENT, WOOLWICH.

Tensile and notched bar impact tests were made on test-pieces taken transversely and longitudinally from all the heat-treated samples. Brinell hardness tests were made with a ball of 10 mm. diameter and a load of 3,000 kg. on this material before turning to tensile test-pieces. Extensions in the tensile test were measured by means of the Ewing extensometer, and the yield-point taken as the load producing an extension of 0·5 per cent. (= 0·01 in.) with the load on.

* Metallurgical Communication No. 2 from the Research Department, Woolwich.

TABLE III.—PARTICULARS OF TREATMENT.

Mark.	Length of Piece Treated.	Treatment. Temperature and Means of Cooling.	Brinell Hardness Numbers. End.	Middle.	End.
	Normalising— Whole tube, 7 ft. 8 in. long	900 deg. C. air	286	269	293
			269	286	293
	Quenching in oil from 850 deg. C. and tempering— Portion of tube, 2 ft. 4 in. long	850 deg. C oil	418	387	418
A	Piece 1 ft. 2 in. long cut from above	850 deg. oil, 650 deg. *furnace* ..	241	235	235
B	Remaining 1 ft. 2 in. from above	850 deg. oil, 650 deg. *water* ..	248	248	241
			255	248	241
	Quenching in oil from 1,000 deg. C. and tempering— Portion of tube, 5 ft. 4 in. long	1,000 deg. oil	430	418	387
C	Piece 1 ft. 2 in. long cut from above	1,000 deg. oil, 650 deg. *air* ..	241	235	241
			235	241	241
D 1 .	Piece 2 ft. long cut from above	1,000 deg. oil, 650 deg. *water* ..	248	248	255
			248	255	255
D 2	Piece 1 ft. long, half of D 1	1,000 deg. oil, 650 deg. water, 650 deg. *furnace*	228	—	228
E 1	Piece 2 ft. long cut from above	1,000 deg. oil, 650 deg. *furnace*..	228	235	235
			228	235	241
E 2	Piece 1 ft. long, half of E 1	1,000 deg. oil, 650 deg. furnace, 650 deg. *water*	235	—	235
			235	—	235

Note.—The treatment in italics is the additional treatment the specimen has received in every case.

TABLE IV.—TENSILE, HARDNESS, AND IZOD TESTS.

Mark.	Treatment. Oil-hardened.	Tempered.	Cooled in	Elastic Limit. Tons per Sq. In.	Yield-Point. Tons per Sq. In.	Maximum Load. Tons per Sq. In.	Elongation per Cent. on 2 in.	Reduction of Area per cent.	Fracture.	Average Brinell Hardness Number.	120 Ft.-lb. Izod Impact Figure Ft.-lbs.
	Transverse Tests. deg. C.	deg. C.									
A	850	650	Furnace	33	38·4	48·2	22·5	56	Fibrous, ¼-cup ..	237	8
B	850	650	Water	31	38·8	48·7	21·0	56	Fibrous, ¼-cup ..	240	59
C	1,000	650	Air ..	31	39·6	49·7	25·0	58	Fibrous, ¼-cup ..	247	27
D1	1,000	650	Water	28	37·6	48·4	25·0	58	Fibrous, ¼-cup ..	239	60
E1	1,000	650	Furnace	30	38·0	47·3	20·0	43	Fibrous, external cracks	238	5
D2	D1 reheated	650	Furnace	31	37·4	47·7	22·5	52	Fibrous, external cracks	234	4
E2	E1 reheated	650	Water	27	36·4	47·0	20·0	45	Fibrous, external cracks and slight flaw	233	61
	Longitudinal Tests. deg. C.	deg. C.									
A	850	650	Furnace	34	38·2	48·0	25·0	66	Fibrous, ¼-cup ..	240	11
B	850	650	Water	32	39·0	49·1	25·0	67	Fibrous, ¼-cup ..	248	86
C	1,000	650	Air ..	32	39·6	49·5	25·0	62	Fibrous, ¼-cup ..	250	42
D1	1,000	650	Water	29	37·8	48·5	25·0	64	Fibrous, ¼-cup ..	244	92
E1	1,000	650	Furnace	27	37·8	48·0	27·0	68	Fibrous, ¼-cup ..	239	8
D2	D1 reheated	650	Furnace	31	36·8	47·4	25·0	66	Fibrous, ¼-cup ..	236	8
E2	E1 reheated	650	Water	25	36·8	47·3	26·0	67	Fibrous, ¼-cup ..	236	82

TABLE V.

Mark.	Treatment. Oil-hardened.	Tempered.	Cooled in	Average Energy absorbed in Breaking Notched Bar. ½ Mm. Radius V-Notch. 120 Ft.-Lb. Izod Machine. Ft.-Lb. Longitudinal.	120 Ft.-Lb. Izod Machine. Ft.-Lb. Transverse.	Charpy Machine Ft.-Lb. Transverse.	Guillery Machine. Ft.-Lb. Transverse.	Mesnager Notch. Guillery Machine. Kgm. Transverse.	Mesnager Notch. Guillery Machine. Ft.-Lb. Transverse.
	deg. C.	deg. C.							
A	850	650	Furnace ..	11	8	5	10	1·8	13
B	850	650	Water ..	86	59	56	66	10·2	74
C	1,000	650	Air ..	42	27	18	28	5·3	38
D1	1,000	650	Water ..	92	60	55	67	10·9	79
E1	1,000	650	Furnace ..	8	5	4	4	0·8	6
D2	D1 reheated	650	Furnace ..	8	4	3	4	0·6	4
E2	E1 reheated	650	Water ..	82	61	51	66	0·8	71

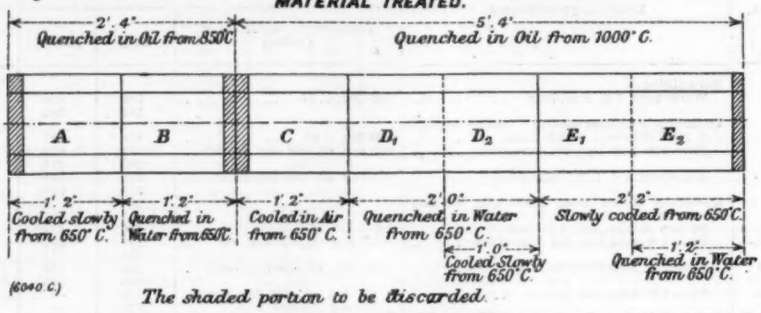
Mark.	Individual Results, Energy absorbed in Breaking Notched Bar. ½ Mm. Radius V-Notch. 120 Ft.-Lb. Izod Machine. Ft.-Lb. Longitudinal.	120 Ft.-Lb. Izod Machine. Ft.-Lb. Transverse	Charpy Machine. Ft.-Lb. Transverse.	Guillery Machine. Ft.-Lb. Transverse	Mesnager Notch. Guillery Machine. Kgm. Transverse.
A	14, 11½, 8	7, 9, 9, 7	4·6, 6·2	8·0, 11·6	1·6, 1·9
B	87, 84½, 85½	60, 63½, 55, 58	55·6, 56·4	65·8	10·1, 10·3
C	44½, 37½, 42½	25, 31, 24, 27½	16·1, 18·8	29·6, 27·4	5·7, 5·1
			18·8, 16·5		
D1	86½, 90, 99	62, 58½, 60, 57½	54·6, 55·6	66·5, 68·0	10·9
E1	9½, 8, 6½	3½, 6, 5, 6½	3·1, 4·1	5·1, 3·6	0·8, 0·8
D2	10½, 7½, 7	5, 5, 3, 4	2·7, 4·1	3·6, 3·6	0·6, 0·6
E2	83, 85, 78	64, 61½, 59, 60½	50·1, 51·0	65·7	10·1, 9·4

Impact test-piece fractures : A, E1, D2, granular.
B, D1, E2, fibrous.
C, fibrous border and streaks, with some granular.

Results are given in Table IV, and load-extension diagrams plotted in Figs. 6 and 7.

Notched-bar impact tests were made with the ½-mm. radius V-notch test-piece in: (1) The 120-ft.-lb. Izod machine; (2) the 30-kilogrammetre Charpy machine; (3) the 60-kilogrammetre Guillery machine; and also (4) with the Mesnager notch test-piece in the Guillery machine. Details of these tests are given in Table V.

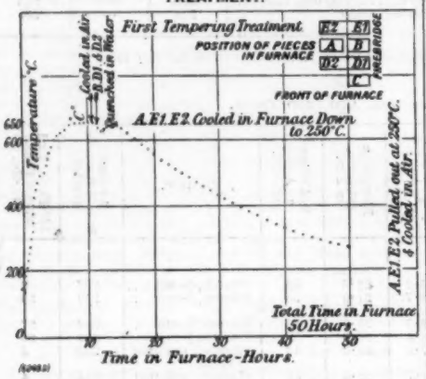
Fig. 3. SUMMARY OF TREATMENT WITH POSITION & DIMENSIONS OF MATERIAL TREATED.



(6040 C.)

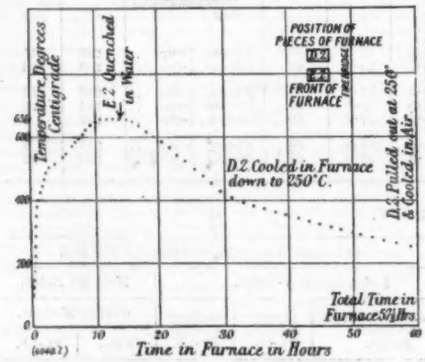
The shaded portion to be discarded.

Fig. 4. TIME-TEMPERATURE CURVE OF TEMPERING TREATMENT.


First Tempering Treatment
POSITION OF PIECES IN FURNACE
FIREBRIDGE
FRONT OF FURNACE
A.E1.E2 Cooled in Furnace Down to 250°C.
A.E1.E2 Pulled out at 250°C. & Cooled in Air.
Total Time in Furnace 50 Hours.
Temperature °C.
Time in Furnace-Hours.

(6040.)

Fig. 5. TIME-TEMPERATURE CURVE OF RETEMPERING TREATMENT


Temperature Degrees Centigrade
E2 Quenched in Water
POSITION OF PIECES OF FURNACE
FRONT OF FURNACE
D.2 Cooled in Furnace down to 250°C.
D.2 Pulled out at 250° & Cooled in Air.
Total Time in Furnace 50 Hrs.
Time in Furnace in Hours

(6042.)

Fig. 6. LOAD-EXTENSION DIAGRAMS OF TRANSVERSE TENSILE TESTS.

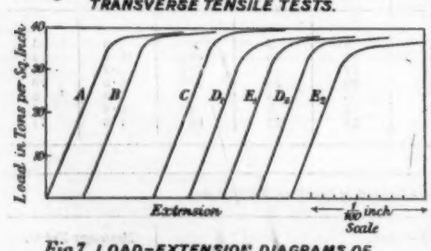
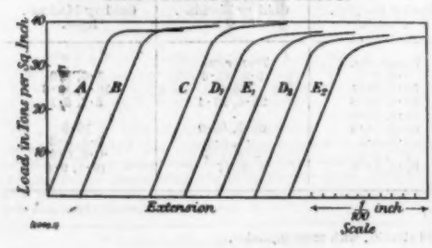


Fig. 7. LOAD-EXTENSION DIAGRAMS OF LONGITUDINAL TENSILE TESTS.



(6043.)

Conclusions.—This trial was intended to test on a larger scale conclusions derived from experiments in the laboratory. These experiments indicated that the following results might be anticipated in the oil-hardened and tempered nickel-chrome steel used.

Treatment.	Impact Figure.
A, E1, D2, involving final slow cooling from 650 deg.	Bad.
B, D1, E2, involving final water cooling from 650 deg.	Good.
C, involving final air cooling from 650 deg.	Fairly good.

The results of the trial entirely confirmed these expectations. In spite of numerical differences in the amount of energy absorbed by test-pieces broken in different machines, all forms of test used gave the same indications.

Further, steels of which the treatment differed only in the rate of cooling from the tempering temperature gave identical microstructure and almost identical tensile tests. The results were also in accordance with previous experience as to the effect of the oil-hardening temperature. After identical furnace cooling in the tempering treatment the steel oil-hardened at 1,000 deg. C. showed a slightly but distinctly lower absorption of energy in the impact tests than that oil-hardened at 850 deg. C. although the very low figure obtained in both cases somewhat masked the effect.

SOME EXPERIMENTS ON NICKEL STEEL.*

By Major N. Hudson, D.S.O., R.A. (35th Advanced Class, Ordnance College).

The object of the following experiments was to determine whether the nickel in a nickel steel will combine with carbon monoxide to form nickel carbonyl gas in a similar manner to that in the well-known Mond process for the purification of nickel,

$$Ni + 4CO = Ni(CO)_4,$$

and if this can be done, to determine the most favourable physical and chemical conditions for the reaction.

Description of Apparatus Used.—The carbon monoxide was obtained in the usual manner by adding formic acid from a dropping funnel to concentrated sulphuric acid,

$$H.COOH + H_2SO_4 = H_2SO_4.H_2O + CO,$$

the carbon monoxide was dried by passing it through $CaCl_2$, and was thence led direct to the reaction tube, which consisted of a silica tube 30 in. long and 0·5 in. internal diameter placed in an Erlenmeyer combustion furnace.

Experiment 1.—An alloy steel containing 23 per cent. of nickel was selected, drillings were taken, packed throughout the length of the reaction tube, and placed in the combustion furnace as shown above.

The gas issuing from the exit tube was lit. When all the burners of the furnace were lit no effect was produced, and the issuing carbon monoxide burnt with its characteristic flame. The effect of extinguishing some of the burners was tried, and finally only three were left burning.

After a few minutes the flame of burning carbon monoxide developed an inner luminous cone and a small mirror appeared on the glass exit tube at the portion made hot by the flame.

On exposing a porcelain plate to the flame, a mirror was also formed, which proved to be nickel by the glyoxime test. On applying a flame at point "A" in the combustion tube another mirror was produced.

Experiment 2.—The action of carbon monoxide at various temperatures was tried on cold steel. The carbon monoxide was passed through a silica tube at temperatures from a red heat to atmospheric temperature, and led through a tube containing the steel drillings as in Experiment 1.

The issuing flame was lit. No indications of the formation of the carbonyl were obtained with the heated carbon monoxide.

A mirror was produced with the carbon monoxide at ordinary temperatures.

Experiment 3.—A nickel steel containing 3·26 per cent. of nickel was selected, and the drillings were placed in the reaction tube.

A very small mirror of nickel was obtained at the mouth of the exit tube when cold carbon monoxide was passed over the cold steel.

The reaction tube was filled throughout its length with the drillings. Higher temperatures were then tried, but no indication of a mirror was produced.

Owing to lack of time, it was not possible to continue the experiments under varying conditions of pressure, and the above must be regarded merely as results of a preliminary investigation.

Conclusions.—1. Carbon monoxide will combine with the nickel in a nickel steel even in the case of steel of a fairly low-nickel content.

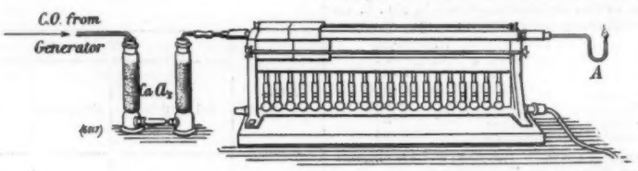
2. The most favourable conditions, as far as can be ascertained in these few experiments, for the formation of the carbonyl appear to be:

(*a*) Low temperatures.
(*b*) Freshly machined metal.
(*c*) Large surface area exposed.

3. As nickel steel is sometimes used in positions where it is liable to exposure to carbon monoxide gas at varying conditions of temperature and pressure, the question of the removal of nickel from its surface in the form of nickel carbonyl may have some practical bearing on such questions as the investigation of erosion, &c.

The above preliminary investigations indicate that the subject is worthy of further experiment under wider conditions of temperature, pressure, &c.

The author is greatly indebted to Professor W. H. Merrett, of the Royal School of Mines, S.K., and to Lieutenant J. S. Cardell, for advice and assistance in these experiments.



(6041.)

* Paper read before the Iron and Steel Institute.

MOULDING-SANDS FOR NON-FERROUS FOUNDRY WORK.*

By P. G. H. Boswell, D.Sc., F.G.S., Professor of Geology in the University of Liverpool.

(*Concluded from page* 420.)

Graphical Expression of Mechanical Analyses.—The expression of mechanical analyses in the form of curves brings out contrasts and similarities in sediments more graphically than does the use of space diagrams. Similar graphs have been used for screening analyses, in connection with water-supply and percolation, in the publications of the United States Geological Survey, and for analyses of iron-moulding sands in those of the Geological Survey of Denmark. The curves here drawn are to be regarded as approximations only, serving to visualise the lists of figures given in the table of mechanical analyses. Reference should be made to the latter.

Cumulative percentages by weight of material above the grade-size (marked horizontally) are set off vertically as ordinates. For example, in the curve (Fig. 1, on page 419) representing a specimen of Belfast, sand, 34·3 per cent. of the sample is of diameter greater than 0·1 mm., and 50·2 per cent. of diameter between 0·1 and 0·01 mm.; the ordinate at the latter grade-size is therefore 34·3 + 50·2 = 84·5 per cent. The horizontal scale adopted is proportional to the logarithms of the diameters quoted, in order to keep the scale representing the various grades within the compass of the page.

The curves are plotted from four to five points, with information for intermediate ordinates obtained from microscopic examination.

Horizontality in any part of the curve means the absence of the grade-size corresponding to the distance that such horizontality extends. Verticality in the graph means the presence of a considerable percentage of the grade-size corresponding to the position of the vertical portion. All the curves eventually turn up at the right-hand end (in the clay-grade portion) when the total reaches, as it must do, 100 per cent. The approach to the upper line may be asymptotic, *i.e.*, the particles may gradually become smaller and smaller to vanishing point; but it is more probable that in most sediments a lower limit of size of particle is reached when the curve turns up thus, ——, Probably, solution eventually causes the disappearance of tiny particles before they disintegrate mechanically.

Representing the mechanical composition of sediments as curves (Fig. 1) obtained by plotting cumulative

* Paper read before the Institute of Metals.

percentages of the various grades against the diameter of particles in the grades, we see that a steel-moulding sand is coarser and yet contains more clayey bond than sands like that from Birmingham used for the casting of brass, &c. Other typical sands used for non-ferrous foundry work are represented also in Fig. 1.

Mineral Composition.—The mineral composition of sands may be determined by certain special methods,* but it is of less importance in the case of moulding-sands than either chemical or mechanical analyses. Nevertheless, a mineral analysis serves two useful ends. In the first place, it enables the investigator to interpret more satisfactorily a chemical analysis, for, in the latter, elements which are actually combined together to produce specific minerals are expressed as oxides. As an example may be quoted the sand from Wombourne, consisting of over 20 per cent. of orthoclase felspar, which explains the presence of 3·43 per cent. of potash (K_2O) shown by the chemical analysis. In the second place, it is frequently possible to identify a sand from its mineral composition, because deposits from different formations and various localities have been derived from different sources. The Bunter sands may thus be distinguished from those of Erith, Durham, Avenuehead, &c., but the limitations of the method are indicated by the fact that it would often be difficult to distinguish examples of the Bunter group of sands from one another.

Co-ordination of Results.—The inter-relation of the chemical and mineral composition has been mentioned above, but from the point of view of practical applications, the bearing of the chemical and mechanical composition of a sand upon each other is of more importance. This inter-relation is shown by making chemical analyses, not of the ordinary sand ("bulk" analyses), but of the various grades as separated by elutriation. The following table indicates the results of such a series of analyses. (The bulk chemical analyses is given in Table I, page 419, and the mechanical analyses in Table II, page 420.)

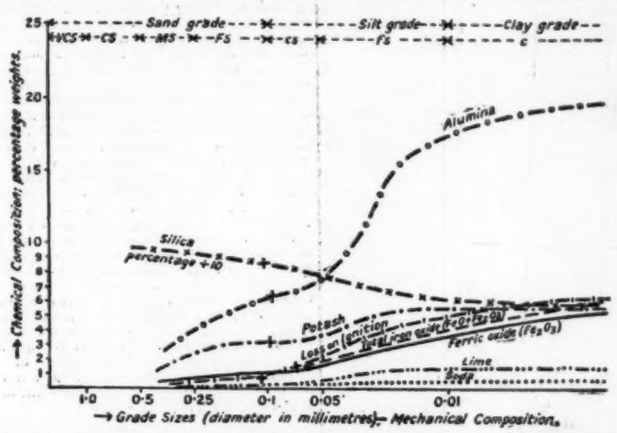


FIG. 2. RED MOULDING-SAND FROM BUNTER DEPOSITS AT COMPTON, NEAR WOLVERHAMPTON. GRAPHICAL REPRESENTATION OF VARIATION OF CHEMICAL COMPOSITION WITH GRADE.

TABLE III.—*Chemical Analyses of Grades; Bunter Moulding-Sand from Compton, near Wolverhampton.*

—	MS. >0·25 and <0·5 mm.	FS. >0·1 and <0·25.	cs. >0·05 and <0·1.	fs. >0·01 and <0·05.	c. <0·01 mm.
	per cent.	per cent.	per cent.	per cent.	per cent.
SiO_2	94·37	89·10	85·31	69·05	58·17
Al_2O_3	2·82	5·32	6·95	14·15	19·58
Fe_2O_3	}	}	1·23	2·70	5·47
FeO	0·46	0·88	0·22	0·53	0·55
MgO	0·17	0·28	0·37	1·05	1·78
CaO	0·16	0·24	0·41	1·27	1·34
Na_2O	0·12	0·15	0·49	0·56	0·38
K_2O	1·57	3·13	3·31	5·45	5·37
TiO_2	0·06	0·21	0·43	0·97	0·73
Loss on ignition	0·48	0·71	1·43	4·28	6·34
Totals ..	100·21	100·02	100·15	100·01	99·71

These results may be graphically expressed by curves, as in Fig. 2.

The most noteworthy features exhibited by Table III and the corresponding diagram are the decrease in silica percentage and the increases in the percentages of alumina, iron oxides, and the "loss on ignition" as the grade-size decreases. The medium sand-grade carries a moderately high percentage of silica, with small amounts of alumina and potash. It may justly be classed as a silica sand, consisting of about 85 per cent. of free silica (as quartz) and 9 per cent. of potash-bearing felspar (orthoclase). Assuming that little or no mica is present, the balance of the alumina and silica would yield about 3 per cent. of clay substance (of theoretical composition, Al_2O_3, $2SiO_2$, $2H_2O$); about 0·5 per cent. of hydrated iron oxide also occurs.

The increase in alumina, ferric oxide, and the loss on ignition (the last-named consisting almost entirely of combined water), as the grades become smaller in size, points to the increase in the proportion of clay substance and limonitic matter (hydrated ferric oxide), which together constitute the "bond" of the sand. A mineral analysis indicates that muscovite mica (silicate of hydrogen, aluminium and potassium) is present, and the quantity increases with decrease in grade-size down to, at any rate, the silt grades. Assuming, for the purposes of calculation, that it is absent in the clay grade, we find that the latter consists of about 21 per cent. free silica, 32 per cent. felspar, 36 per cent. clay substance, and nearly 6·4 per cent. of hydrated ferric oxide.

The most fusible constituents in a sand are the compounds of the alkalies, sodium and potassium, and of the alkaline earths, lime and magnesia. It has been stated that iron acts also as a flux in refractory materials, but the statement requires modification. Ferrous compounds tend to fuse rather readily, but certain ferric compounds, particularly the oxides, are highly refractory if the conditions, as is always the case in moulding-sand practice, are oxidizing and not reducing. As an example, it may be mentioned that the bond of the most successful steel-moulding sands is largely hydrated ferric oxide, and to a less extent clay substance.

Since the alkalies yield more fusible compounds than the other constituents, it is evident that the mineral felspar is undesirable in a sand which is required to withstand high temperature. Felspar is accordingly found in small amounts only in the most refractory sands. For the casting of non-ferrous metals and alloys, however, the temperatures reached are not sufficiently high to cause the mineral to flux, and its presence (or past occurrence) in a sand may be of advantage on account of the contribution yielded to the bond of the material by its decomposition products.

Felspar in the fresh state is clear and colourless, being composed of the silicates of aluminium, sodium, potassium and lime. Potash-felspar (orthoclase) is by far the most commonly occurring species in sedimentary rocks, and its decomposition may be taken as typical of the group. Orthoclase has a chemical composition corresponding to the formula Al_2O_3, K_2O, $6SiO_2$. "Weathering" causes it to lose its clear character and the grains or crystals become cloudy with decomposition products.

The carbonic acid gas of the atmosphere and soil frequently acts as the weathering agent, and in the presence of water leaches out part of the potash as carbonate, which is removed in solution. The result is the production of finely divided flakes of potash-mica (approximating to $KH_2Al_3(SiO_4)_3$ in composition). The formation of these tiny crystals of mica is frequently a resting-stage in the process, but eventually the whole of the potash is removed, and clay, which in its pure form is known as kaolin or china-clay, of composition Al_2O_3, $2SiO_2$, $2H_2O$, is produced. The cloudiness seen in grains of partially decomposed felspar, as well as the clay substance often associated with them, is due to a mixture of fine micas and clayey material, which together constitute an excellent bond in a sand. The well-known Scottish "rotten rocks" are so-called on account of their friability, which has resulted from the decomposition of felspar originally present in the sandstone. These rocks are mainly used in iron and steel-casting, but a few, including that from Avenuehead, have been used for non-ferrous work.

It is noteworthy that the rolling out of clays increases their plasticity; similarly, the milling of moulding-sands increases their bond very markedly. The effect is probably to cause the flaky crystals of kaolinite and micas to lie more or less parallel to one another. Whilst milling should be sufficient to break down lumps of a sandstone into individual grains and to "knead" the bond round each, it should not be so heavy as to crush the quartz-grains.

In the case of felspathic sands like that from Compton mentioned above, milling doubtless crushes down the more decomposed grains of felspar, thus releasing an additional quantity of bond. The increase in the amount of bonding material as a result of milling is indicated by the following mechanical analyses of the same sand from Wolverhampton before and after being treated in a pan-mill:—

—	CS. >0·5 and 1 mm.	MS. >0·25 and <0·5	FS. >0·1 and <0·25	s. >0·01 and <0·1	c. >0·01.	S. Total Sand Grade. >0·1 mm.
	pr. cent.	pr. cent.	pr. cent.	pr. cent.	pr. cent.	pr. cent.
Before milling ..	trace	27·8	64·6	2·7	4·9	92·4
After milling	0·2	20·0	59·5	12·2	8·1	79·7

The best form of milling machine appears to be the ordinary pan (or chaser) mill with a fixed (non-perforated) pan. It is essential that the rolls should not be too large or heavy, and it is often desirable to have one of them cogged or fluted longitudinally around the periphery. Disintegrators or pulverisers of various types are in use in many parts of the country in foundries as well as in sand-pits (*e.g.*, at Mansfield, Birmingham, Ormskirk, &c.), but whilst they are very effective in crushing the sandstone, it is a debatable question as to whether or not the strength of bond developed is as great as that of pan-milled material. The difficulty of the relatively small output of pan-mills is, however, overcome.

The "Bond" of Moulding-Sands.—In metal-founding, the natural bond of moulding-sands is often supplemented by artificial bonds, such as treacle, flour, dextrin, sulphite-lees, &c. Many of these artificial bonds are, like clay and ferric hydroxide, colloidal bodies, which are characterised by their exhibition of surface phenomena—in this case particularly by their power of absorbing water. The weathering of many rock-forming minerals gives rise to colloidal bodies known as "gels." These colloids are apparently constituted with a honeycomb or cell-like pattern which enables them to hold considerable quantities of liquid. The water which is absorbed into the "cells" of clay is termed "micellian" water, and differs from hygroscopic water in that it cannot all be driven off at 110 deg. C. The plasticity of clays may be increased by an admixture of other colloids, such as colloidal silica, alumina, gallo-tannic acid, agar-agar, &c. The absorptive power of clay, in the matter of both gases and solutions, increases, according to Senfft, with the limonitic content. J. M. van Bemmelen showed, as long ago as 1878, that the amount of "hydrate water" of ferric oxide was variable and accidental. When just dry at 15 deg. C., the compound is able to take up over six molecules of water per molecule of ferric oxide. This fact throws interesting light upon the strength of the ferruginous bond in moulding-sands, and the power possessed by them of holding considerable quantities of water,* without actually become wet. For foundry purposes the smallest quantity of water, consistent with obtaining the required bond, should be used. The proportion is usually about 5 per cent., or even less.

The burning of clay for the purpose of making bricks is an everyday occurrence. The clay is thereby "porcellanised," volatile constituents such as water being driven off, and new minerals produced. The addition of water to burnt clay does not, in ordinary circumstances, produce the colloidal substance again. Hence the gradual wastage of a bonded sand in a foundry and its need of "revival." The foundryman asks that his sand shall be long-lived—that is, shall not dehydrate and "go dead" too readily. Where the hot metal touches the mould, the clay bond is undoubtedly killed, but not so the ferruginous bond. The sands with the longest life are often rich in the latter. Floorsands in greensand moulding are frequently revived with such a sand as that from Mansfield or Birmingham, and in the case of dry-sand moulding, these and other Bunter sands and also Barrow sand have been found to be very efficacious for the same purpose.

The ferruginous bond in moulding-sands is usually the cause of the production of a smooth sound surface to the casting, particularly in the case of steel. In non-ferrous foundry practice it is usual to ensure the smoothness of the skin by painting the surface of the mould, or "facing" it with a layer of finer sand "facing sand") or a wash. The washes used for painting the moulds in non-ferrous work have usually either china clay or a graphitic material as a base. Graphite (plumbage) is itself sometimes used; at other times "Scotch blacking," which is a mixture of charcoal and graphite, is employed, and flour has also been used. A suspension of the powder in water may be assisted by the addition of a little borax or molasses.

For the making of "cores" in British foundries, "a compo" (or composition) moulding-sand is usually made up from an ordinary sand such as that from Mansfield, together with fragments of broken graphite crucibles, &c. The admixture of coarser material ensures the good venting of the cores. At times the sand alone is used. Oil-bonded cores (where the oil is generally a commercial linseed oil, such as "Baltic seed oil"), unlike those used in steel founding, have not met with success in non-ferrous founding at home, but they are adopted extensively in America, where a fairly coarse high-silica sand is the base. Sands from Lumberton and Howell, N.J., are so used.

The moulding-sand in common use for non-ferrous work in the United States is that from Albany, N.Y., and is remarkably similar in feel, texture and behaviour to corresponding British sands like that from Erith ("Thames sand").

Distribution of Works and Sands connected with

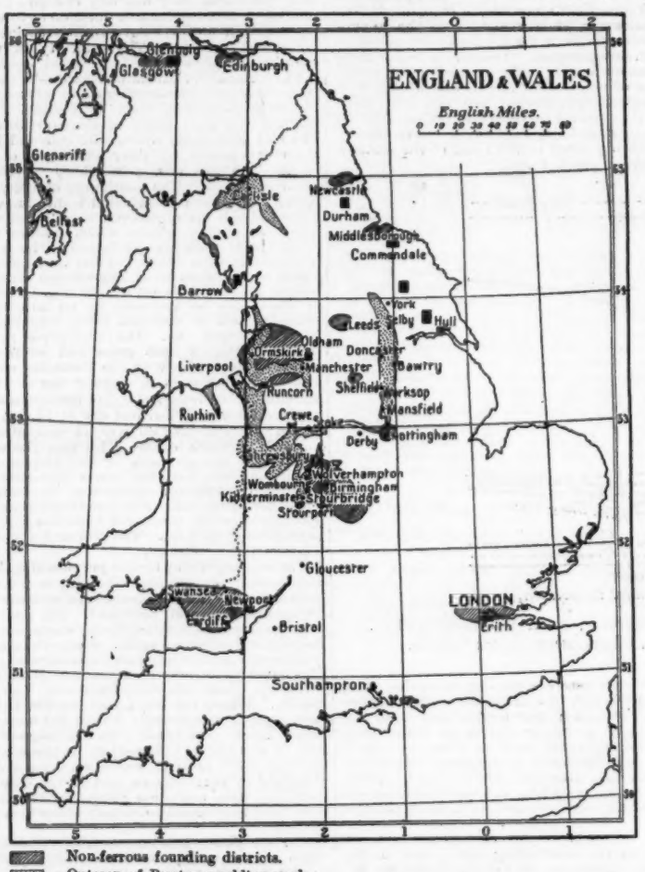
* *Op. cit.*, page 15.

* Some sands are able to take up as much as 13 per cent. by weight.

Non-Ferrous Foundry Practice.—Despite the widespread distribution of moulding-sands eminently suitable for casting non-ferrous metals and alloys, the number of different sands in general use, both in Britain and America, is remarkably small. Considerable transport is consequently involved, but, as will be seen from the following list of available resources, much of it could be avoided. Moreover, sands such as those used for casting iron, brass, bronze, &c., will not stand even so great a freight-rate as those used in steel manufacture, where the supplies are by no means so widespread. The margin of profit is too low, and the cost of transit too high, to permit such a commodity as sand to be unnecessarily carried from one part of the country to another.

It may therefore be of service to draw attention to the geographical distribution of the non-ferrous foundries and the supplies of moulding-sands suitable for them. This has been done in Fig. 3.

Only the areas containing towns with a number of foundries (usually over ten) could be considered. Almost every town of any size in Great Britain has one or more brass-foundries connected with it, and it would have been impossible to indicate them all upon the map.



Non-ferrous founding districts.
Outcrop of Bunter moulding-sands.
Occurrence of other moulding-sands for non-ferrous founding.

FIG. 3. SKETCH MAP SHOWING LOCATION OF CHIEF DISTRICTS ENGAGED IN THE FOUNDING OF NON-FERROUS METALS AND ALLOYS, AND THE OCCURRENCE OF SUITABLE MOULDING-SANDS.

The district *par excellence* for non-ferrous foundry work (brass, bronze, aluminium, &c.) is, of course, the Black Country in general, and Birmingham in particular. In Birmingham alone there are nearly 400 foundries concerned in the work, but it was a fortuitous circumstance that the city itself was built upon the red Bunter moulding-sand so valuable to the industry. Indeed, the sand has been worked in the heart of Birmingham, less than a mile from the Town Hall, for more than four generations, and has been used for the casting of gold, silver, nickel, copper and brass, as well as the more modern work in phosphor-bronze, white alloys, aluminium, &c.

The exhaustion of the supplies of Birmingham sand being within sight, the resources of the adjoining area of the Bunter outcrop are being drawn upon, and Stourbridge, Wolverhampton, Compton, Wombourne, Kidderminster and Stourport are now contributing their quota.

The Metropolitan area is next in importance, but falls far behind the Black Country. It is served in the matter of moulding-sand by the excellent deposits at Erith, Charlton, Woolwich and Rochester (both from quarries and dredged from the river-bed). The Glasgow, Manchester and Liverpool districts follow London in importance. The Glasgow area is in part supplied by Carlisle sand, partly by Scottish "rotten rocks," but largely by Belfast sand shipped across the North Channel. The Triassic sand from the Isle of Arran may prove of value in the future. (The Edinburgh-Leith district, which is less important, uses considerable quantities of both Erith and Mansfield sands, that from Erith being shipped in the Thames and unloaded at Grangemouth.) Manchester, like Birmingham, is built upon first-class moulding sand, but the area is being rapidly built over. Supplies of sand for the South Lancashire area, including Liverpool, are also drawn from Ruthin, Ormskirk, Runcorn, Oldham, and the Wolverhampton country. Sheffield, Hull, Leeds and Belfast rank next in importance; these districts (except Belfast) draw their sand from the Bunter deposits of Worshop, Hull, Hensall and Mansfield, and from the glacial beds of Oldham, near Manchester. Permian sand from Pontefract is also used.

The industries on Tyneside and in the Tees Valley use sand from Erith (which has been water-borne), Durham and Mansfield. Durham sand shows a remarkable resemblance to Erith sand in texture, chemical composition, and behaviour in the foundry—a fact not so well realised as it might be. South Wales draws largely upon the Bunter sands of Stourport, Kidderminster and Belfast. The Nottingham-Derby district finds valuable supplies near at hand in the area from Mansfield to Nottingham.

From the above outline it is evident that a few well-known sands, such as those from Belfast, Birmingham, Mansfield and Erith, are used very extensively and are transported considerable distances. It is also clear that every non-ferrous foundry district, whilst located intentionally upon or very near to a coal-field, is also either on or close to highly suitable sand supplies. In many cases these are insufficiently well known. It would not be possible in a paper of ordinary length to describe all the small local deposits of sand which have been used in small quantities for, say, the casting of brass.

For details relating to other supplies, and the location, description, cost, by whom worked, &c., of the resources here mentioned, reference may be made to the memoir on refractory sands cited earlier in the paper.

It is interesting to find that, although every country in the world probably contains sands suitable for the founding of non-ferrous metals and alloys, such relatively cheap sands as those from Erith, Mansfield and Manchester have been exported, not only to European countries, but also to South Africa, India, Australia, and even to the United States of America—almost, in fact, to the home of the very similar sand from Albany, New York.

The chemical analyses quoted above were kindly carried out by Dr. H. F. Harwood, of the Imperial College of Science and Technology, at the request of the Ministry of Munitions. The writer wishes also to acknowledge the assistance rendered by Mr. G. S. Sweeting, of the same college, in making a number of the mechanical analyses. Much of the work was carried out in the geological laboratories of the college, by permission of Professor W. W. Watts, F.R.S. The writer, in conclusion, desires to express his sincere thanks for the cordial welcome extended to him at all times by the owners and managers of sand-quarries and foundries throughout Britain.

APPENDIX.

At the suggestion and request of the Publication Committee of the Institute of Metals, the following brief summary is given of the author's memoir upon British Resources of Refractory Sands mentioned in the foregoing paper. The publication was issued during the war, at the instruction of the Ministry of Munitions, for the purpose of indicating the character, location, and extent of the available supplies of sands suitable for furnace and foundry purposes, particularly in connection with steel manufacture, but also for the cast-iron and non-ferrous industries.

The plan and scope of the work may be outlined as follows. In order that investigation and research into the difficulties attendant upon the use of sands (which have at no time very closely approached the ideal) might be undertaken or continued in works' laboratories, the earlier chapters dealt generally with sands, their origin, uses and methods of study and analysis. Following a short account of industrial processes, for the successful carrying on of which refractory sands are required, there was given a full description of a typical high-class furnace (i.e., high silica) sand from Leighton Buzzard, Bedfordshire, and of a steel-moulding sand from St. Erth, Cornwall. From the properties of these sands, the several characteristics desirable in furnace or foundry sands were deduced, and detailed descriptions of various British resources of these materials were given. Each source of supply was considered under the following heads: By whom worked, location on maps, situation, geological formation, detailed description, analyses, transport and available resources. Method of treatment of sands and preparation for use in the furnace or the foundry were outlined, and numerous tables of analyses with accompanying diagrams were added for reference.

Many of the best Continental and American refractory sands were also described for the purpose of instituting a comparison with British materials. The location of the latter with regard to the distribution of the metallurgical industries, coalfields, railways, canals and waterways, &c., was discussed and illustrated by means of maps. Finally, certain economic considerations relating to the importation and cost of foreign sands, and the workability, treatment, transport and development of British materials were dealt with, and an appeal made for greater investigation and exploitation in the future of home and colonial resources.

THE HALIFAX EXPLOSION OF DECEMBER 6, 1917.—The explosion which wrecked Halifax two years ago surpassed all previous explosions in destructive effects and in the quantity of explosive involved. The munition ship Mount Blanc collided with the steamer Imo while entering the Narrows on the way into the inner harbour of Halifax, Nova Scotia. According to Dr. Harold L. Bronson, of Dalhousie University, Halifax (Proceedings of the Royal Society of Canada, vol. xii, pages 31-35), the Mount Blanc carried about 2,500 tons of high explosives, i.e., about 2,144 tons of picric acid, the rest being trinitrotoluene, guncotton and monochlorbenzene. This last product was stored on deck and was supposed to have caught fire first by the heat of the impact, that however, is uncertain, as are also the figures given. The fire burned for about twenty minutes, during which the ship drifted close to pier No. 6 on the Halifax side, where it grounded, apparently just before the big explosion which was preceded by three minor explosions. The detonation wave probably started at a speed of 5,000 m. per second, but that speed would rapidly decrease. All buildings within half a mile from the explosion were totally destroyed, and hardly anything left habitable within a mile; no part of Halifax escaped damage; damage was done at Windsor, ten miles to the north-east, and the shock was felt at North Cape Breton, 135 miles away. Dr. Bronson himself was in the University building, 3,500 m. away from the ship, when he felt a shaking. It seemed to be directly under him and thinking of some accident in the boiler room, he walked over that way, but had hardly stepped 30 ft. when a crash came which destroyed the doors and windows. The earthquake shock itself was slight, possibly because the ship was still in the water when the explosion occurred; the first shaking mentioned had indeed not been more severe than that caused by blasting on a railway cutting in the neighbourhood. The seismograph at the University recorded three shocks, the first at 9.05 a.m., the second five minutes later, and the third about an hour later. This suggested three explosions, the first being the most severe, and it was believed that there were two later explosions, low down in the bottom of the ship, and that these did not cause air-waves; both Bronson and W. C. Cope, the explosive expert, consider this suggestion as improbable, however. Unfortunately the boom of the seismograph was dislocated by the first shock, so that the two other records are questionable. Other records do not appear to be available. Most of the damage was apparently due to the air-wave.